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Using Virtual Reality in (Investigating-Simulating-Reconstructing) the Crime Scene

[1]Dr. Amr Ezzat Elhaw, [2]D. Jamal Alshehhi

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Abstract: Currently, there's an increasing amount of academic research aimed to the advancement of virtual environments and situations that possess the capacity to offer fully immersive alternative experiences encompassing visual, tactile, and auditory modalities. Such endeavors hold promise for achieving a considerable degree of efficacy when appropriately applied. By conducting an in-depth examination of immersive virtual reality and its technology components, this study aims to explore suitable methodologies for efficiently reconstructing virtual criminal scenes. The process of crime scene reconstruction is of considerable importance in the field of criminal investigation as it aids in establishing the sequence of events that transpired. The primary objective of forensic crime scene documentation is to achieve non-invasive, high-resolution measurement and enhance the level of understanding. Nevertheless, conventional techniques are insufficient for the comprehensive reconstruction of complete crime scenes. The integration of three-dimensional visualization techniques enables the comprehensive examination of several forms of evidence collected at the crime scene, facilitating the construction of a coherent narrative. The information is conveyed through immersive virtual reality (VR) technology instead of being exhibited on conventional computer screens. The interconnections across evidence chains facilitate the attainment of a comprehensive reconstruction of a crime scene. This is accomplished by the utilization of expert knowledge and computer-assisted forensic technologies to scrutinize the origins of damage and ascertain the individuals potentially responsible. The utilization of three-dimensional imaging methodologies enables a more comprehensive examination and a variety of valuable analysis, including precise quantification, in many types of criminal incidents.

***Keywords*: -** *Virtual reality, crime scene, investigation, simulation, reconstructing, evidence, investigators, forensic*

1- Introduction

Virtual Reality (VR) has emerged as a prominent technique within the field of computer technology, facilitating the creation of virtual environments. Essentially, the software in question enables users to create and simulate scenarios. The primary focus of the development of this Virtual Reality technology is its use in the realm of game development.and numerous occupational domains. The rationale behind the adoption of Virtual Reality stems from its ability to offer a wide range of possibilities. For instance, in the past, architects were responsible for the creation and refinement of various structures such as buildings, roads, bridges, and other client-specified constructions. Through the act of drawing, individuals would gain the ability to visually perceive the potential challenges that may manifest in the future. The utilization of Virtual Reality technology enables architects to create and refine architectural designs within a computerized environment. This approach has the advantage of time efficiency, as the computer assumes a significant portion of the architect's responsibilities by seamlessly integrating with existing plans and generating proposed outcomes (Bardi, J., 2019)

The advancement of science and technology has significantly influenced contemporary society, particularly in relation to the operations of law enforcement organizations. The incorporation of novel computer technology into the training system

[1]*dr.amr.elhow.police@gmail.com*
Orcid.0009-0000-1254-2323
Jamal.a.alshehhi@gmail.com
Orcid.0009-0009-3204-4060
[2]*Department of law and criminal investigation*
Police Science Academy-Sharjah
United Arab Emirates

of law enforcement agents is of paramount significance. This procedure is linked to the efficient execution of tasks under circumstances that closely resemble professional environments. Acquiring proficiency in the intricate skill set required to perform a thorough examination of an incident scene is a formidable challenge, necessitating the utilization of simulated scenarios that encompass diverse criminal investigations within a multifaceted setting. The authors have devised a system of virtual training grounds with the purpose of simulating real-life event scenarios using currently available virtual reality technology. This system is specifically designed to train law enforcement professionals (Mazuryk, T. & Gervautz, M., 2019)

Upon the arrival of an investigation team at the crime scene, they have a limited time during which they must diligently amass a substantial quantity of evidentiary material. The evidence that can be considered includes, but is not restricted to, fingerprints, photographs or videos, blood samples, and any other form of biological evidence. The presence of time constraints gives rise to several potential hazards. These risks include the potential inadequacy of evidence collection, the likelihood that the evidence may not fully capture the entirety of the scene, and the potential for damage or destruction of the evidence. The objective of our research is to clarify the role of VR in investigating, simulating and reconstructing crime scenes. The utilization of this software enables both the Crime Scene Investigation (the CSI) team and the court to reexamine a crime scene by inputting just the essential elements of the crime under investigation, relying on previously gathered data and witness testimonies. In lieu of employing costly cameras to capture an excessively authentic scene, there is a need for a computationally efficient solution due to the substantial time necessary for rendering the environment, as well as the necessity for advanced gear to handle the data (Woodford, C., 2019)

1-1-Objectives and methodology

A crime scene is a vital part of an investigation. There are however, depending on the situation and crime, issues connected to physically being at the scene; risk of contamination, destruction of evidence or other issues can hinder the criminal investigators to stay, visit or revisit the scene. It is therefore important to visually capture the crime scene and any possible evidence in order to aid the investigation. This thesis aims to, with an initial research question, map out the main visual documentation needs, wishes and challenges that criminal investigators face during an investigation. In addition, with a second research question, it aims to address these in a Virtual Reality (VR) design and, with a third research question, explore other advantages in the investigation process could benefit from it. This was conducted through a literature review, interviews, and workshops and provides suggestions with the approach of the implementation Model of Design. The results from the methodology were thematically analyzed and ultimately summarized into five key themes. These, together with various design criteria and principals, acted as design guidelines when creating a high fidelity VR design(Dormehl, L., 2017)

1-2-the (concept, background) of virtual reality

Virtual reality (VR) refers to a simulated world, generated via the utilization of software and hardware, which aims to replicate real or fictional scenarios. The technology provides users with a fully immersive experience within a digital three-dimensional environment, enabling them to engage with their virtual surroundings through the utilization of input devices such as motion sensors and hand controllers. In order to investigate the practical implementation of virtual reality (VR), it is imperative to establish a precise and unambiguous definition of VR(The Franklin Institute, 2020)

Hoffmann asserts that virtual reality (VR) represents a fundamentally distinct form of communication between computers and individuals. It can be perceived as a platform for human-computer interaction, wherein individuals engage with a computer-generated virtual simulation.

Virtual reality (VR) has been used as a scientific research tool since the early 1990s. Over the years, it has demonstrated great potential due to its ability to enhance realism and lower expenses. Virtual reality (VR) is particularly advantageous in the field of criminal investigation due to its ability to create immersive virtual settings. Virtual reality (VR) utilizes a virtual environment (VE) to create a very

accurate representation of a crime scene. Motion trackers are frequently employed to monitor the movement of users and subsequently modify the virtual environment (VE) accordingly. Virtual reality (VR) possesses the capability to effectively transport users to other environments, hence establishing its potential as a potent tool. Within these virtual settings, individuals have the ability to navigate and interact with their surroundings. The user's movements are monitored and feedback is provided to the virtual environment (VE) in order to adapt to the user's actions. Virtual reality (VR) distinguishes itself from conventional media due to its exceptional capacity for generating a significantly elevated level of interactivity.

Virtual Reality (VR) possesses two distinguishing characteristics that set it apart from traditional media: interactivity and immersion(T. P. Kersten, F.Tschirschwitz & S.Deggim, 2017)

In contrast to conventional media, the user's movements and actions exert a significant influence on the medium, resulting in a highly interactive experience. The level of immersion in a virtual environment can be attributed to the degree of realism experienced within the same environment (Suncksen, M., Hamester, F. & C.Ebert, L., 2019)

As the degree of sensory input from the conventional sensory realm diminishes the perception of complete engagement for the user increases.

1-3-The concept of the crime scene and the advantages of using virtual reality in the field of law enforcement

The term "crime scene" refers to a specific location where a criminal act has taken place, and where real evidence related to the crime can be gathered. Crimes encompass a range of unlawful activities, such as murder, car accidents, theft, and assault, among others. Upon the arrival of an investigation team at the site of the crime, there exists a limited time period within which they must quickly collect an enormous amount of evidentiary material. The nature of evidence collected from a crime scene is dependent upon the specific sort of crime committed. For example, in cases of murder, blood samples may be sought as crucial evidence, whereas in instances of burglary, the presence of fingerprints left behind becomes significant. The collection of evidence encompasses the acquisition of photographs and videos captured at the location of the criminal incident, together with any biological evidence procured. While the team's evidence collection process may demonstrate thoroughness, it is possible that certain evidence could be overlooked. For instance, the photographs taken may not provide a comprehensive depiction of the entire scene. (Pool, R., 2019)

Additionally, there is a potential for biological evidence to be compromised or destroyed due to contamination or mishandling during the preservation of such evidence. Hence, the presentation of photos to juries restricts their perspective, thereby exacerbating the challenge of reaching a conclusion. And it can be said that the advantages of these process might be cleared through the following points

-Practical training without the inherent risks.

-Police officers have access to training opportunities.

-The expense associated with recruitment and training has been reduced.

-Enhanced interventions for assisting individuals with post-traumatic stress disorder (post-traumatic stress disorder).

-The potential for liability cases is mitigated.

1-4-Design Rationale and technology tools of VR

1-4-A-Hardware

The Head-Mounted Display (head-mounted display) HMD provides users with an immersive experience through the utilization of three-dimensional graphics and auditory stimuli. Additionally, the device incorporates a sensor for location monitoring, as well as motion controllers to facilitate system navigation. Refers to a collection of computer programs, data, and instructions that enable a computer system (Neeter, E., 2018)

1-4-B-Software

Software is a comprehensive assemblage of computer programs, data, and instructions that facilitate the functioning of a computer system.

-Unity is a highly sophisticated game engine that provides extensive support for the development of three-dimensional graphics and the integration of scripting through a programming language. The

inclusion of this feature set offers significant benefits in enabling the integration of dynamic actions into models. Unity provides a variety of texturing and lighting techniques that possess the capacity to augment the simulated world

-. Autodesk Maya, The use of Autodesk Maya, widely recognized software for 3D modeling, was employed during the production of the television series Sherlock to create elaborate models for various objects. What set it apart was the incorporation of a human rig, which proved to be beneficial in our progress

-Blender, a free 3D modeling software, is employed for the production of diverse objects with Autodesk Maya. (Siebert, , Dobay, , Affolter, R. & Ebert, L. C., 2018)

-The Adobe Photoshop program is a commonly employed software application used for the purpose of image manipulation. The use of Autodesk Maya and Blender has been observed in the application of texturing and painting techniques to the modeled objects..

In the preliminary stages of the investigation, it is imperative for the investigator to compile an inventory of items commonly encountered at a crime scene. This inventory should encompass various elements such as human cadavers in diverse orientations, edged weapons, firearms, blunt instruments, and discernible traces of blood. The items were generated and textured utilizing both Blender and Maya software applications. The models were exported to the Unity platform, where modifications were made to the textures and size of each model. To include Virtual Reality utilities and development kits into the Unity platform, a framework can be established. This framework enables users to navigate using thumb sticks and employ the right controller for pointing and selecting.

Following this, the subsequent phase entailed the development of the simulation framework in order to facilitate the exploitation of the imported objects. The construction of the environments involved the utilization of scene files that contained the essential data menus and code for the development of objects. The user is afforded the opportunity to navigate between several scenes through the utilization of a menu selection script, which is conveniently situated on the head-up display. The user has the capacity to create and assemble a simulated crime scene (O'Sullivan, Holzinger, Wichmann, Saldiva, Zatloukal, K,2018)

2-Investigation crime scene by Virtual reality

The idea includes the user engaging into a virtual world that gradually transitions into a tangible and fully realized setting. Instead of relying solely on static images generated by 3D laser scanners, certain crime scene reconstructions incorporate objects within their software. These objects, such as tables, chairs, knives, and shattered glass, are deemed pertinent to the crime scenes. The intention is to create interactive software that allows users to access comprehensive details about each object. In a stationary visual composition, only a single facet of each object is observable. The design of virtual reality (VR) allows users to engage with the virtual environment by doing various tasks, such as picking up a piece of evidence and turning it (Garland, J.; Ondruschka, B.; Stables, S.; Morrow, P.; Kesha, K.; Glenn, C.; Tse, R, 2020)

At the commencement of the task, the user's visual field is occupied by a centrally positioned screen. The menu displays were developed with the intention of minimizing the need for extensive head motions, as users are required to visually locate and select buttons.

When a user initiates the creation or modification of a scene, they are presented with a screen that provides them with the option to choose the environmental setting for such scene. The lighting for the scene and the perception of being in a tangible environment, as opposed to a virtual realm, are influenced by the five available choices: Day, Night, Cloudy, Raining, and Snowing. In the context of incorporating objects from the available inventory, the user is responsible for modifying the size and appearance of said objects in order to closely align with the characteristics of the actual crime scene (Harris, E.J.; Khoo, I.H.; Demircan, E,2022)

In situations where there is reasonable suspicion of a criminal offense, a forensic examination of the crime scene is conducted at the specific site in question, as well as its immediate vicinity, contingent upon the circumstances. Typically, the

initial individuals present at the site of a crime are the criminal investigators, who commence the process of engaging in dialogue with those in the vicinity. The primary objective of the forensic inquiry is to ascertain the presence of a criminal act and, if confirmed, to determine the modus operandi employed. The definition of a crime scene can be characterized as "any location or object that encompasses, or has the potential to encompass, tangible evidence indicating the occurrence of a criminal act or establishing a link between an individual and said act." In the context of crime scene examination, it is imperative to incorporate many sorts of evidence, if feasible. These include physical evidence, circumstantial evidence, and eyewitness testimony. Prior to any alteration of the crime scene, it is imperative for the crime scene investigator to ensure the accurate documentation of the scene. The documentation of the appearance, position, and orientation of potential evidence is crucial during the process of safeguarding it. The utilization of visual documentation and visualization techniques. Photographic and videographic techniques are employed to visually document the crime scene and effectively secure potential evidence. Photography, encompassing both classic and panoramic techniques, serves as a significant means of visual record and evidence collection. In the context of photographing crime scenes, it is imperative to adequately address the potential requirements for capturing comprehensive, close-up, and highly detailed visual documentation. The acquisition of a substantial number of informative images is of utmost significance, as photos may initially appear relatively inconsequential but might subsequently accrue considerable value (Mohammad, N.; Ahmad, R.; Kurniawan, A.; Yusof, 2022)

The potential to enhance several stages of the traditional investigative process exists with the incorporation of Virtual Reality technology into Crime Scene Investigation. The incorporation of Virtual Reality (VR) technology within the realm of Crime Scene Investigation (the Crime Scene Investigation) SCI holds promise for enhancing certain facets of the investigative process. However, it is crucial to acknowledge that VR cannot entirely supplant the essential components of preservation, processing, and reconstruction that constitute the fundamental pillars of any investigation. The utilization of virtual reality technology holds the promise of substantially diminishing the temporal demands associated with both processing and rebuilding procedures.

The technique described above mostly involves the utilization and subsequent storage of the collected material (ELKarazle, K.; Raman, V.; Then, P , 2022) The act of capturing images of digitally created content, along with other types of documentation, in a random sequence can present difficulties in achieving a holistic comprehension of the interconnectedness between all the documented evidence and its relevance to the scene. Comprehensive visual documentation of a crime scene possesses the capacity to diminish the necessary staff presence at the scene. One plausible strategy for mitigating the risk associated with tampering with evidence is ensuring that staff personnel, regardless of their physical location at the scene, are equipped with easily available and comprehensively documented data pertaining to the incident. By employing this approach, the probability of inadvertent alterations to the evidence can be reduced. Video recording is a supplementary method of visually documenting a subject, alongside photography. It aids in capturing a more complete representation of the surrounding environment. The application of this tactic is commonly utilized as a first method of visually documenting a crime scene. The significance of an early portrayal of the crime scene remains substantial, even if video recordings generally provide less detailed information compared to photographs. Furthermore, it is utilized for the objective of documenting the process of conducting walkthroughs with witnesses and other individuals who are present at the location (Toy, S.; Secgin, Y.; Oner, Z.; Turan, M.K.; Oner, S.; Senol, D, 2022)

A VR design could challenge the lack of understanding regarding distance, depth, , volume field of view etc. of photos and video recordings. through connecting crime scene photos and get a

more coherent perspective of the crime scene by "jumping" between the 360° photos than only viewing traditional ones,

Traditional photographs and video recordings may accidentally miss the documentation of items or regions that were initially deemed insignificant but subsequently proved to be of significance. Rapidly panning the video camera across regions with limited resolution may lead to suboptimal visualization. This matter is resolved by capturing 360° photographs that encompass the entirety of the crime scene, so allowing the user to virtually revisit the original location. Virtual reality (VR) has the potential to serve as a supplementary tool to photographs and video recordings, providing spatial and comprehensive information that may be absent in conventional forms of study. Virtual reality (VR) has the potential to effectively tackle the problem of an overwhelming amount of visual evidence seen during an investigation, as highlighted by a confidential informant (CI). This task might be accomplished by consolidating substantial quantities of graphic content within a single location(Fang, Y.T.; Lan, Q.; Xie, T.; Liu, Y.F.; Mei, S.Y.; Zhu, B.F , 2020)

A virtual reality (VR) design has the ability to serve as a supplementary and comprehensive tool, facilitating the collection and organization of digitalized documentations while establishing connections and relationships among them.

The imperative of visiting the crime scene has been recognized as a fundamental requirement, indicating that relying just on visually documented evidence is inadequate for the purposes of conducting an investigation. If a visualization tool were available to crime investigators, allowing them to quickly access the necessary images, it might be inferred that significant savings in energy, time, and resources could be achieved by virtually experiencing the crime scene. Additionally, it has the potential to facilitate the dissemination of information to stakeholders participating in the inquiry, hence eliminating the need for their physical presence at the scene. This technique also has the potential to facilitate the visualization of crime scenes that are no longer accessible or those associated with unresolved cold cases. Discussions conducted at the National Forensic Conference (Near Field Communication (NFC) have indicated that witnesses can exhibit hesitancy or fear when it comes to revisiting crime scenes. The use of a virtual reality (VR) visualization technology that enables unrestricted movement could potentially facilitate a simulated visitation of the site, so contributing to the enhancement of the investigative process in a secure manner. This concept could likewise be employed to validate. By employing a mathematical correlation between the coordinates of object and picture points obtained from digital photos, it becomes feasible to get three-dimensional information, hence enhancing the authenticity of the user's activity. This phenomenon enhances the likelihood of experiencing a sense of presence within the virtual crime scene (Esaias, O.; Noonan, G.W.; Everist, S.; Roberts, M.; Thompson, C.; Krosch, M.N, 2020)

3-Simulationon Crime Scene Using Virtual Reality

3-1-The main factors of simulating the crime scene by virtual reality

The aim is to create an appropriate crime scene simulation utilizing the Unreal Development Engine as a means to convert the crime scene into a virtual environment. In addition, the authors incorporate 3-D reconstruction techniques in conjunction with the Unreal Development Kit (UDK) to facilitate the development of a simulated representation of the Crime Scene. The process of 3-D reconstruction serves a crucial function in generating three-dimensional images. This will enable the Crime Scene Investigation to evolve beyond existing methods(Raneri, D , 2018)

Converting the crime scene into a simulation would effectively limit the risk of overlooking any potential evidence. During the investigation of a crime scene, it is imperative for the investigator to efficiently gather as much evidence as possible in order to promptly remove the crime scene area. As a result of this, there is a significant likelihood that the investigator may overlook or fail to properly consider crucial pieces of evidence. The inclusion of a transformative process would afford the investigator the opportunity to repeatedly examine

the scene, so facilitating the identification and collection of evidence(Home, P.H.; Norman, D.G.; Williams, M.A, 2021)

A framework was devised for the purpose of Crime Scene Investigation. The framework commences by acquiring data as its initial input. This pertains to the photographs that are captured at the crime scene. The content would be presented in a visual format, mostly relying on images. The entry of data into the virtual engine is necessary in order to configure it correctly. Additionally, the next step involves the process of loading data and constructing scenarios. This implies that the virtual engine will initiate the loading process of the file and thereafter undertake the reconstruction of the potential simulation, which occurs in two primary steps. (Li, X.; Sandler, H.; Kleiven, S, 2019)

Firstly, it is imperative to revisit the crime site. By employing virtual reality technology, the user is afforded the opportunity to repeatedly engage with the crime scene, so enabling a heightened level of experiential immersion. This will enable individuals to acquire a comprehensive understanding of the situation and grasp the intricacies of the issue. This will additionally afford individuals the opportunity to engage with it at their discretion. In the absence of a virtual reality setting, the investigator would be limited to a single opportunity to analyze the crime scene, in contrast to the virtual reality simulation of the crime scene. By utilizing a virtual reality simulation, the detective would have the capability to expeditiously and economically revisit the crime scene. Participants have the option to repeatedly traverse the scene in order to limit the possibility of overlooking any potential evidence (Baier, W.; Warnett, J.M.; Payne, M.; Williams, M.A, 2018)

Furthermore, collaboration is another important aspect to consider. In this context, the investigator may seek assistance from specialists through the utilization of shared virtual reality technology. In many instances, the unavailability of experts at the crime scene necessitates the utilization of virtual reality technology to facilitate collaboration and seek guidance from these experts. This would additionally enable the investigator to have a deeper understanding and even glean insights from the criminal's characteristics. This would additionally prohibit the omission of any stages. An incident of homicide occurred within a motel, during which the designated specialist was unavailable, with their anticipated availability scheduled for one week later. One potential solution is the conversion of the crime scene into a virtual reality environment, which may subsequently be accessed and analyzed by an expert upon their return. This approach enables the expert to allocate sufficient time for acquiring knowledge and comprehending the issue, thereby providing informed guidance to the investigator in effectively resolving the case.

In addition, the subsequent topic of discussion pertains to the process of knowledge acquisition. This implies that the judiciary and prosecution have the capacity to acquire knowledge pertaining to the circumstances surrounding the ongoing investigation. This would additionally afford the judges the opportunity to authentically immerse themselves in the depicted scenario. This would afford the prosecutor and the judge with a more comprehensive understanding of the case, since they would not solely rely on textual information, but also have the opportunity to visually perceive it. It can be argued that visual perception provides a greater level of comprehension compared to textual interpretation. For example, in the case of the gas station murder, the judge and prosecutor involved may employ virtual reality technology to examine the details of the case. This immersive experience would enable them to gain a comprehensive understanding of the incident, facilitating the delivery of an equitable decision and ensuring a just legal process(Sieberth, T.; Seckiner, D.; Dobay, A.; Dobler, E.; Golomingi, R.; Ebert, L, 2021)

Finally, the concept of conformity. This implies that the virtual reality simulations are resistant to tampering, hence enhancing the ability of agencies to effectively observe, control, and report on investigative tasks. This also demonstrates that the issue will be resolved in a thorough manner, without resorting to bad practices or employing shortcuts in the investigative process (Engstrom, P, 2019)

The presence of these four elements as advantageous factors would contribute to a more promising future

for investigators, potentially enabling them to solve cases more efficiently. This is due to the ability of virtual reality technology to provide repeated examination of evidence, hence expediting the investigative process. This virtual reality system has the capability to accurately replicate a variety of scenes as specified by the users. This scenario possesses the potential to exhibit complete authenticity, a crucial requirement for all crime scenes. This virtual reality simulation has the potential to be utilized by investigators situated in diverse geographic regions.

3-2-Process On Virtual Reality In The Ceime Scene

The use of Virtual Reality in the context of Crime Scene Investigation requires a unique approach that differs from the conventional methods employed in traditional forensic reconstruction. Notwithstanding these disparities, the technique will remain grounded on the fundamental principles of forensic reconstruction (Dath, C , 2017)

The use of virtual reality technology in the field of Crime Scene Investigation has promise for introducing innovative methodologies. Nevertheless, it is crucial to develop a solid groundwork based on conventional approaches. The potential benefits of using Virtual Reality (VR) technology into Crime Scene Investigation (the CSI) via the adoption of a thorough procedural framework include increased efficiency and reduced time consumption. Through a series of processes as outlined below,(Jinming Wang,others 2019)

3-2-A- laser scanning

The first stage of the procedure involves data preparation. Following the acquisition of 3D data by laser scanning, photogrammetry, PMCT, and other scanning techniques, it becomes imperative to undertake the process of converting this data into surface data, hence leading to the development of a substantial quantity of faces. Before transforming the result into data for analysis, it is necessary to adequately prepare the whole area and properly record all components in order to get the most favorable opportunities. In order to get a complete and exact outcome, it is important to use a scanner with a resolution of 100. In addition, it is necessary to join the scanner to the photogrammetry system in a following manner. This approach is deemed essential due to the heightened level of concentration required in order to achieve precise simulation (Maneli, M.A.; Isafiade, O.E , 2022)

Moreover, the selection of a high frame rate is crucial in order to minimize any inaccuracies in the simulation. This method will also include the incorporation of suitable hardware and software to improve the quality of visualization.

3-2-B-walkthrough

The process of walkthrough preparation and system setup includes the user's validation and implementation of the simulation. It is important to determine the efficacy of the system's operation. In this phase, the participants will use the HTC Vive virtual reality headset, which is integrated with lighthouse tracking technology and handheld controllers. These devices will be handled by a gaming laptop that has been optimized specifically for virtual reality activities.This will allow individuals to customize the system, and the process of customization will consider several elements (Kottner, S.; Flach, P.M.; Gascho, D.; Ampanozi, G.; Thali, M.; Ebert, L.C , 2020)

To effectively address the issue of insufficient evidence, it is crucial to execute the proposed course of action. Conducting this walkthrough is important to address any small adjustments inside the simulation, including alterations to tables, chairs, and displays, with the aim of mitigating their impact. The importance of this issue is in its capacity to ascertain the degree of precision attained in the simulation. The use of this strategy will effectively minimize the risk of unintentional misplacement of small information.

It is important to engage in this particular undertaking in order to minimize the potential for misplacing little items. In order to address any small adjustments in the simulation, such as revisions to tables, chairs, and displays, it is essential to do a comprehensive walkthrough. The importance of this issue is in its capacity to ascertain the degree of accuracy and precision attained in the simulation. The use of this step will effectively reduce the likelihood of any small errors or misplacements (Lindgren, N.; Henningsen, M.J.; Jacobsen, C.; Villa, C.; Kleiven, S.; Li, X , 2023)

Furthermore, it is important for persons to sufficiently prepare the allocated area for the execution of the simulation. The establishment of a designated area for users to participate in simulation activities is crucial. For instance, it is necessary for individuals to establish a specifically allocated space to facilitate the execution of the simulation. Additionally, it is crucial to provide users with a specified spatial milieu through which they may walk and interact. The allocated area enables users to navigate without constraints and offers a graphical depiction of the simulated situation (Vidoli, G.; Devlin, J.; Watson, J.; Kenyhercz, M.; Keller, J, 2020)

The use of simulation in the investigation carries substantial significance for a multitude of reasons. This capability will allow the investigator to get a clear picture and precisely discern little particulars. The interviewee utilizes the event scene tour as a method to freely examine and traverse the location. The incorporation of an eye witness in the investigation may be advantageous, as it would furnish a comprehensive depiction of the occurrences and their progression. For instance, the observer will be invited to engage in a simulated setting wherein they will be furnished with suitable apparatus. The individuals will be accompanied by the investigator in order to submit their testimony. Throughout this procedure, they will be given the chance to recount the chain of events that led to the incidence. Furthermore, the researcher will possess the capacity to investigate the adjacent area with the purpose of acquiring further proof (Galvin, R.S, 2020)

The process to create post-scene walkthrough data includes the use of an automated saving method to guarantee the retrieval and safe storage of all captured data from devices. Within this particular segment, the implementation of extensive data sets functions as a safeguard against the manipulation of data. The data shown refers to the material that is being viewed by users. The possible augmentation of the data might be facilitated by increasing the size of the audience present during the crime scene simulation. For instance, the simulation will be subjected to scrutiny by researchers and those who have directly seen the event. When participants activate the gears, they will carefully scan their surroundings and capture any visual information they detect. This information will be preserved for eventual utilization in legal processes. The aforementioned feature has substantial significance, as it may be used within the judicial system to enhance judges' understanding of legal matters and promote the efficient dispensation of justice (Villa, C.; Hansen, N.F.; Hansen, K.M.; Hougen, H.P.; Jacobsen, C , 2018)

3-2-C-The establishment of secure evidence storage

The subject matter under consideration pertains to the storage and safeguarding of evidence. The management of security in a distributed environment involves the oversight of data management, system integrity, and cyberspace security. Once the data has been entered into the virtual reality (VR) system, it is subsequently stored inside a cloud-based database.The database in question is subject to limitations on accessibility, with only the investigators assigned to the case and higher-ranking authorities being allowed unique powers to obtain the data. The extent of data alteration is limited to the modification of information acquired during the inquiry, just inside the Cloud database. Nevertheless, attaining a condition of "zero risk" poses significant challenges because to the dependence on Cloud outsourcers and operators for safeguarding data. The Cloud database has proprietary data security measures in order to limit the potential for unauthorized access. In order to enhance protection against tampering of evidence, the Cloud database is seamlessly connected with Blockchain technology. Blockchain-as-a-Service (cloud computing) is used for this particular purpose. The designated investigators are granted access to the data via the use of the public key, however the secret key is securely maintained inside the Blockchain. By using this methodology, the information related to the case is protected from any possible alteration or obstruction(Cubie, A.; Theologis, T.; Wolpert, D.; Abboud, R.; Baker, R.; Stebbins, J , 2017)

3-2-D-Experiment and Analysis

A three-dimensional image should generated using the photographs acquired from a simulated crime scene.and the positions of everything should be modified using data obtained from a terrestrial scanner and closed-circuit television cctv (surveillance cameras). The resulting image should be inputted into the Unreal software. Initially, a stationary crime scene is establishing and preserved for future access and study. Subsequently, a three-dimensional animated film is generating utilizing a CAD (computer-aided design) methodology, enabling virtual engagement between the wounded and weapons. The film provides an analysis of the bullet's effect on the human body, the characteristics of bloodstain patterns, and the post-fall positioning of the body.

The footage are altering in a manner that ensured the bloodstain and body position seen in the end product was consistent with those observed at the original crime scene. This information facilitating comprehension regarding the trajectory of the projectile and the location of the perpetrator (Khan, M.H.; Farid, M.S.; Grzegorzek, M , 2021)

The virtual reality scenes were saved in a cloud environment utilizing a Blockchain service, and appropriate privileges were allocated. As the case advances, the relevant data pertaining to the case can be stored, retrieved, and modified from a cloud-based system. Upon the conclusion of the case, the data residing in the cloud may be transferred to alternative data storage mediums, such as magnetic tapes, owing to the substantial file size of the virtual reality (VR) scenes. The aforementioned strategies are employed specifically for the purpose of implementing the virtual background, with the desired outcome being a heightened level of immersion within the virtual environment. The participant has the ability to assume several roles inside the virtual environment. The individual in question has the ability to assume the positions of perpetrator, observer, or arbiter in order to achieve the desired objective. The various positions exhibit distinct levels of utilization within the virtual setting (Thakkar, N.; Pavlakos, G.; Farid, H , 2022)

The presence of a witness has the potential to contribute to the development of the virtual situation. Implementing this approach has the potential to enhance the dependability of the virtual environment. In addition, The role of the criminal yields valuable information that can contribute to the inquiry. The perspective of the judiciary plays a crucial role in assessing the admissibility of virtual reality (VR) as evidence.

Virtual environments are designed to create realistic crime scenes for crime detectives, but they also serve an important function in courtrooms. It is imperative to thoroughly assess all collected data prior to its presentation as evidence in order to uphold the integrity of the data. Therefore, judges have the option to utilize either the animated movie or the virtual reality scenario in order to obtain a comprehensive and accurate understanding (Dustin, D.; Liscio, E, 2016)

4- Replication and reconstructing the Crime Scene

4-1-Replication and reconstructing the Crime Scene

The first and important phase in crime scene reconstructing includes the replication of the genuine crime scene. The meticulous reproduction of crime scenes, prior to any contamination from human action and other circumstances, significantly contributes to the investigative process. 360-degree photos of the crime scene are collected prior to the arrival of the investigator at the site of the crime. In an alternative approach, the production of a 360° video involves the comprehensive capture of the whole crime scene via the process of recording from all angles. The process of integrating these pictures into a unified three-dimensional (3D) image is achieved by the use of specialized techniques in video editing. Furthermore, the use of data acquired from CCTV (closed-circuit television) systems, when available at the crime site, together with terrestrial laser scanners, serves to augment the veracity of the simulated crime scene. The acquired data is processed and integrated into virtual reality (VR) software in order to accurately reconstruct the crime scene. The potential of virtual reality (VR) is in its capacity to transform architectural data into knowledge that is conducive to study, hypothesis formulation, and drawing conclusions (Villa, C.;

Lynnerup, N.; Boel, L.W.T.; Boldsen, J.L.; Weise, S.; Bjarnø, C.; Larsen, L.K.; Jørkov, M.L, 2022)

-A static crime scene is created by using pictures, which enable crime investigators to conduct a thorough analysis of the crime scene. The information gathered from the simulated crime scene is as follows:

-One kind of evidence that may be used in forensic investigations is biological evidence, which includes tissues, hair, and other similar materials.

The examination of bloodstain patterns, including the analysis of factors such as the angle of blood spatter on a surface, impact splatter, satellite splatter, and similar characteristics.

- Establish if the physical remains have undergone postmortem displacement. 4- Ascertain whether the criminal act was intentionally perpetrated or occurred accidentally.

There are five pieces of evidence indicating the presence of a tool or tool mark in relation to the crime (Olver, A.M.; Guryn, H.; Liscio, E , 2021)

The process of recreating a crime scene offers crime investigators the advantage of being able to analyze the scene at their own discretion and access it at their convenience.

4-2-Reconstructing the crime scene by VR

Investigations of crime scenes are intricate processes that heavily depend on minute particulars. It is difficult to reconstruct precisely what transpired. Investigators can more precisely recreate crime scenes and gain a deeper understanding of what transpired or why it occurred by utilizing virtual reality.

Video surveillance footage and additional sources, including GPS tracking devices and eyewitness testimonies, are utilized to gather data. Subsequently, this data is integrated into a three-dimensional model of the crime site, enabling investigators to virtually traverse it (Hwang, J.; Jung, M.C , 2015)

Fresh investigators assigned to a case can rapidly become acquainted with the intricacies of the crime. Additionally, reopened dead cases will be considerably simpler to examine. Instead of laboriously sifting through numerous reports, novices can review the case details from their office while donning a headset.

The functional requirements

The functional requirements relate to the specific capabilities and functionalities that a system or software must possess in order to meet the demands and requirements.

The system will enable users to construct the scene incrementally.

The system offers users an inventory menu through which they can input objects into a given area. Individuals have the ability to physically grasp an

item and relocate it to a desired location, while also having the capacity to alter its orientation.

Users are able to modify the scene and its associated components,. Scenes that are intended to be preserved for subsequent editing purposes.

The implementation of a menu that includes a confirmation of the date and time, as well as the ability to watch various sceneries.

Non-functional requirements

The system will:

• operate smoothly to prevent users from experiencing motion sickness

• allow scenes to be displayed in a clear manner

4-2-A-3D Reconstruction Methods Assessment

The primary objective of a virtual crime scenario is to create a highly immersive virtual environment that accurately simulates a real-world physical location. The portrayal of illegal behaviour has historically been a pervasive theme. The investigation concerns the identification of the best appropriate methodology for the specified objectives of the application. Numerous methodologies for reconstructing virtual environments are used within the domain of virtual scenario reconstruction (Galligan, A.A.; Fries, C.; Melinek, J , 2017)

The methodologies used in this research include photogrammetry, 3D laser scanning , RGB-D mapping, and the integration of 3D gaming engines such as Unreal 4 and Unity 3D (Abreu de Souza, M.; Alka Cordeiro, D.C.; Oliveira, J.; Oliveira, M.F.A.; Bonafini, B.L , 2023)

Firstly, it is necessary to establish the specification of pertinent assessment characteristics in order to assess the appropriateness of specific approaches. The pace of reconstruction is considered to be one of the most crucial factors. Another factor to consider is the amount of visual realism, as it has a direct impact on the degree of immersion experienced in virtual scenarios. The maintenance of design severity, encompassing both software/hardware and human capabilities, is a crucial aspect that constitutes the third key factor in the review process. Scalability and versatility parameters refer to the capacity of specific reconstruction approaches to be effectively employed in a wide range of scenarios, therefore being the last criterion for evaluation. In order to summarize, we will evaluate a specific method for reconstructing virtual crime scenarios based on the following criteria:

4-2-B-Evaluation of 3D Reconstruction Methods

The use of 360° photography enables the swift and effortless acquisition of a comprehensive representation, hence enhancing the precision of crime scene documentation through the application of this technology. Another notable feature of this technology is its capacity to enable users to zoom in and see the environment from vantage points that may be physically unattainable in reality. The inclusion of several views can provide additional valuable insights into the sequence of events at a crime scene, hence enhancing investigators' ability to develop informed theories.

After the completion of the 360-degree photography of the crime scene, the recorded data can be transformed into a virtual walkthrough, enabling jurors to engage in an immersive experience through the utilization of a virtual reality headset. The jurors can access a simplistic stereoscopic virtual reality (VR) equipment, such as a Google Cardboard, using their smartphones. By employing this approach, the jurors are able to meticulously examine the physical environment, juxtaposing it with the testimony and other evidentiary materials presented in the Court, so facilitating their determination of the verdict in the case (Saiti, E.; Theoharis, T, 2022)

Designing a realistic three-dimensional model of space that encompasses all essential objects and qualities, with the ability to be efficiently created and adaptable for use in a police department context, is a crucial challenge within the current scope of research methodologies. Firstly, a detailed discussion of certain approaches is presented.

1-Photogrammetry

Photogrammetry is a field which includes techniques from various academic areas, including as optics and projective geometry. The process of taking digital images and performing photogrammetric processing involves a series of distinct processes that enable the creation of 2D or 3D digital models of the object as a final outcome. The fundamental nature of a picture is the transformation of a three-dimensional scene onto a

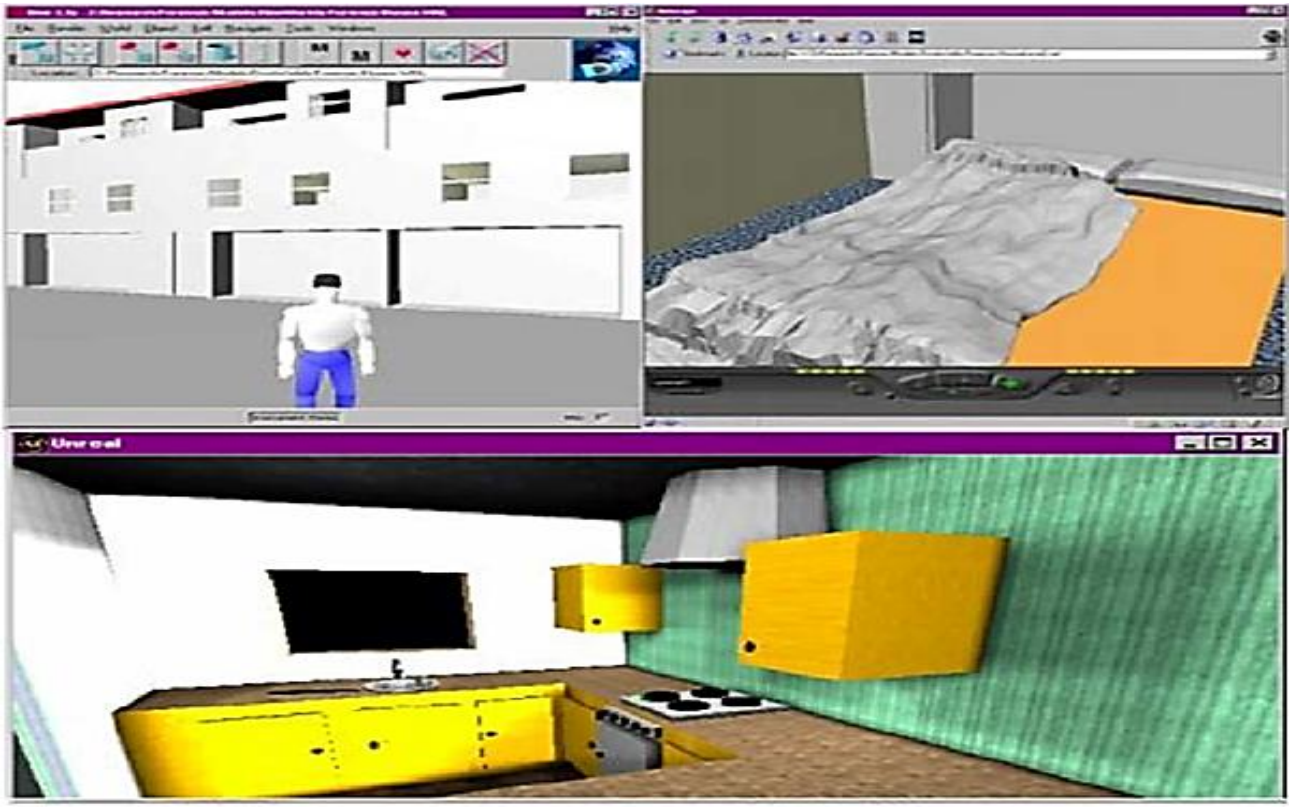
two-dimensional plane, resulting in the loss of depth perception. The 3-dimensional coordinate representing a particular location in a picture is limited to lying in the line of sight. It is not feasible to ascertain the specific point on the line that corresponds to the picture point just based on a single image (Villa, C.; Flies, M.J.; Jacobsen, C , 2018)

The determination of a 3D point's position can be achieved by intersecting the projection rays of two available images.

The aforementioned procedure is commonly known as triangulation. The crux of this procedure is in the interconnections among various perspectives, which serve to communicate that corresponding groups of points inherently possess a certain structure and that this structure is intricately linked to both the positions and the calibration of the camera (Kottner, S.; Thali, M.J.; Gascho, D , 2023)

The determination of depth poses a significant challenge in the overall process, as it involves the calculation of the three-dimensional component that is absent from a given image. The primary concern at hand pertains to the correspondence problem, which involves the identification of corresponding elements between two images. This enables the subsequent triangulation of the matched elements in three-dimensional (3D) space. After obtaining several depth maps, the next step is the amalgamation of these maps to generate a conclusive mesh. This is achieved through the calculation of depth and subsequent projection out of the camera, a process commonly referred to as camera registration (Maiese, A.; Manetti, A.C.; Ciallella, C.; Fineschi, V , 2022)

The process of camera calibration will be employed in order to determine the precise locations where multiple meshes generated from depth maps can be merged together to form a bigger composite, so enabling the availability of multiple perspectives for observation. At the stage of Material Application, a fully formed 3D mesh is obtained, which may serve as the ultimate objective. However, it is typically desirable to transfer the color information from the original pictures onto the mesh. The methodology encompasses the utilization of random image projection onto the mesh, as well as the integration of textures to achieve super resolution (Flies, M.J.; Larsen, P.K.; Lynnerup, N.; Villa, C , 2018)



2-3D laser scanning

The process of 3D laser scanning involves the use of laser technology to capture and record the physical characteristics and dimensions of an object or environment in three-dimensional space (Michienzi, R.; Meier, S.; Ebert, L.C.; Martinez, R.M.; Sieberth, T, 2018)

The primary objective of a 3D scanner often revolves around the generation of a three-dimensional model. The 3D model comprises a point cloud composed of geometric samples located on the surface of the topic. Subsequently, these points might be employed to infer the form of the topic, a procedure commonly referred to as reconstruction. If data on color is gathered at every individual spot, it becomes possible to ascertain the colors present on the surface of the topic as well. There are some similarities between 3D scanners and cameras. Similar to the majority of cameras, lidar systems possess a conical field of view. Additionally, akin to cameras, its ability to gather data is limited to unobstructed surfaces. While a camera is capable of capturing color information pertaining to the objects it observes, a 3D scanner is designed to acquire distance information regarding the surfaces inside its visual range. The output generated by a 3D scanner provides information regarding the distance from the scanner to the surface at every individual point within the captured image. This enables the identification of the three-dimensional position of each point in the picture (Pesce, M.; Galantucci, L.M.; Lavecchia, F , 2016)

In the majority of circumstances, a solitary scan will not yield a comprehensive representation of the object under examination. To comprehensively gather information about all aspects of the subject, it is typically necessary to conduct many scans, often numbering in the hundreds, from various directions. The scans must be integrated into a shared reference system, a procedure commonly referred to as alignment or registration, and subsequently combined to generate a comprehensive 3D model. The process of transitioning from a singular range map to a comprehensive model is commonly referred to as the 3D scanning pipeline (Kottner, S.; Schaerli, S.; Fürst, M.; Ptacek, W.; Thali, M.; Gascho, D , 2019)

While the process of generating a 3D scan of the interior of a small space may be relatively straightforward from a technology standpoint, it is important to note that laser scanning is not limited solely to indoor environments. Several laser scanning systems with superior capabilities have the ability to operate in outside environments, such as traffic intersections, desert and woodland areas, as well as rooftops. Nevertheless, the presence of desolate surroundings, such as an expansive field or an elongated vacant street, presents additional obstacles due to the potential for distances that exceed the maximum range permitted by the scanning device. For the 3D scanner to accurately capture a reference point that can be subsequently interpreted by the computer as a wall or object, it is imperative that the item being scanned is situated within the operational range of the scanner. In the event that the distance exceeds 300 meters, the laser scanner will fail to capture any data (Leipner, A.; Baumeister, R.; Thali, M.J.; Braun, M.; Dobler, E.; Ebert, L.C , 2016)

The utilization of 3D scanners for crime scene reconstruction in various criminal instances is undeniably beneficial. Moreover, this technology possesses additional forensic applications that extend to diverse categories of crimes, situations, and occurrences. Additional categories of cases that can make use of a three-dimensional (3D) scanning and reconstruction include:

Traffic collisions

Train, plane, or public transportation crashes

Snowboarding or skiing accidents

Personal Injury cases slip and fall, etc.

Vandalism, arson, etc.

Terrorist attacks or bombings

Active shooter scenarios, mass shootings, or murder suicide incidents

Riots or civil unrest

High speed car chases, police pursuits, illegal street racing

3-RGB-D mapping

The process of RGB-D mapping involves the creation of a three-dimensional representation of an environment using both color (RGB) and depth

RGB-D cameras are sensory devices that acquire RGB images in conjunction with depth information for each pixel. RGB-D cameras utilize either active stereo or time-of-flight sensing techniques to produce depth estimations across a significant number of pixels.

Although sensor systems with such capabilities have been developed on a customized basis for several years, it is only recently that they have been made available in formats that are appealing for research purposes beyond specialized computer vision groups. The primary factors influencing the development of the latest RGB-D camera systems are computer gaming and home entertainment applications (Villa, C, 2017)

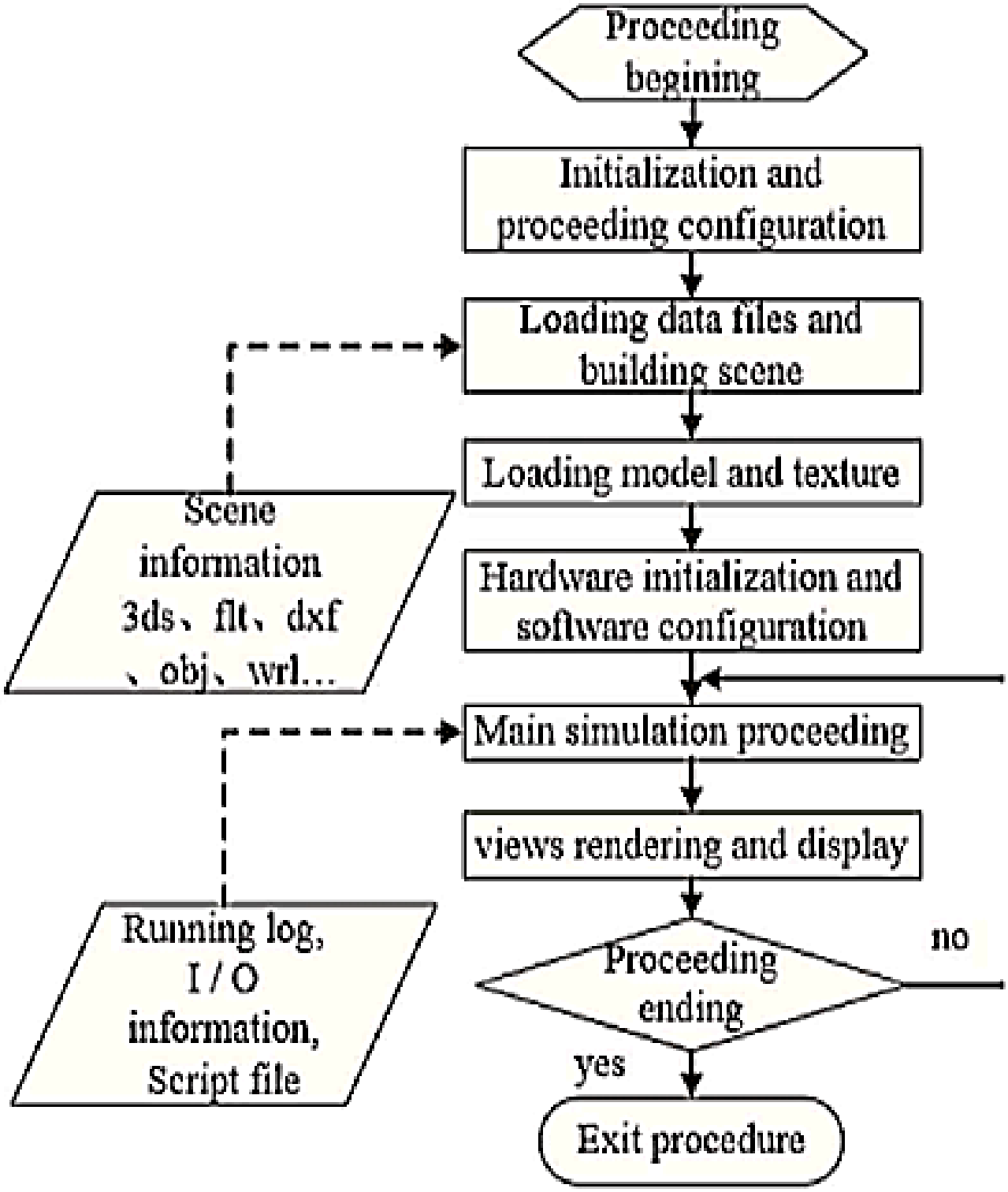
4-3D Game Engines

The topic of discussion relates to three-dimensional (3D) game engines.

Currently, the Unreal Engine 4 and Unity 3D stand out as the most widely utilized 3D engines in contemporary times. The creation of a virtual environment can be achieved manually using these engines. The development of a virtual environment, including all essential models, can be achieved through a straightforward process utilizing a drag and drop graphical user interface. The utilization of engines in computer games and various virtual reality applications is extensive. The challenge associated with 3D scene reconstruction pertains to the significant time required for the process, as well as the inherent complexities involved in achieving an accurate copy of a real-world place. However, there exist potential opportunities to integrate these engines with the aforementioned methodologies (Kottner, S.; Ebert, L.C.; Ampanozi, G.; Braun, M.; Thali, M.J.; Gascho, D , 2017)

Finally, the animation process poses complications because to the inherent variability in individuals' movements, each characterized by their distinct range of motion. In what manner should this diversity be taken into account during the animation process? The accurate and dependable utilization of 3D technologies in forensic reconstructions and interpretations necessitates the careful examination of these significant factors. One such approach may be the virtual recreation of the scene, wherein various scenarios are visually replicated in accordance with the statements and instructions provided by suspects, victims, or witnesses. In the current Danish practice, it is imperative that all pertinent stakeholders are in attendance during the process of 3D reconstruction. Furthermore, they should be afforded the opportunity to pose inquiries and make requests for the re-simulation of particular scenes. In order to uphold the veracity of the evidence and the precision in representing bodily motions, it is advisable for a proficient team of three-dimensional (3D) designers or programmers specializing in gaming to engage in a collaborative effort with the scientific law enforcement personnel and forensic experts, such as pathologists or anthropologists. The objective of this collaborative effort is to proactively mitigate any potential instances of manipulation pertaining to the 3D models, while simultaneously ensuring the preservation of the accuracy and authenticity of the evidence. It is imperative to meticulously document each virtually rebuilt scenario for prospective utilization in legal actions. The ultimate determination of the most credible scenario should be entrusted to the court (Slot, L.; Larsen, P.K.; Lynnerup, N , 2014)

By applying the method of virtual "recreation," investigators can investigate many scenarios, thus enhancing the transparency and reliability of the investigative procedure. The utilization of technological advancements and scientific knowledge has the potential to enhance the attainment of a more comprehensive and impartial evaluation in the context of criminal investigations and judicial processes (Buck, U.; Busse, K.; Campana, L.; Schyma, C , 2018)



5-The positive AND the negative impacts of VR

5-1-The positive Impact of Virtual Reality on Crime Scene Reconstruction for (investigators-judges-witnesses)

The advent of virtual reality (VR) has brought about significant transformations across many sectors, including gaming, healthcare, and presently, the domain of forensics. The utilization of artificial intelligence (AI) has significantly enhanced the precision and effectiveness of crime scene reconstruction. The implementation of this groundbreaking technology is revolutionizing the methodologies employed by investigators in the analysis and interpretation of evidence, hence

resulting in heightened efficacy in criminal investigations (Villa, C.; Jacobsen, C, 2019)

One of the primary benefits associated with the utilization of virtual reality (VR) technology in the process of crime scene reconstruction is the capacity to replicate the scene within a simulated environment. Through the process of recording and digitizing crime scene data, investigators possess the ability to generate a three-dimensional (3D) representation, enabling them to virtually navigate and explore the scene. This immersive encounter offers a distinct vantage point and empowers investigators to discern possible evidence that might have been disregarded in the primary inquiry.

Moreover, the integration of virtual reality (VR) technology with artificial intelligence (AI) algorithms has the potential to augment the precision of crime scene reconstruction. The utilization of AI-powered algorithms enables the examination of gathered data, encompassing various forms such as images, videos, and witness statements, with the purpose of identifying latent patterns and connections that may not be readily discernible to human investigators. The utilization of this analytical capacity can facilitate investigators in reconstructing the chronological order of events and identifying probable suspects with greater efficiency (Ramme, A.J.; Vira, S.; Hotca, A.; Miller, R.; Welbeck, A.; Honig, S.; Egol, K.A.; Rajapakse, C.S.; Chang, G , 2019)

Furthermore, virtual reality (VR) technology can serve as a valuable tool for training forensic specialists, in addition to its role in assisting investigators with crime scene reconstruction. Trainees are able to enhance their skills through the utilization of a realistic virtual environment, wherein they can engage in the simulation of diverse crime scenarios. This enables individuals to acquire significant practical knowledge without the necessity of accessing authentic crime scenes. Additionally, virtual reality (VR) training offers the advantage of being readily repeatable and customizable, allowing forensic experts to concentrate on particular areas of specialization. This ensures that they are adequately equipped to handle any potential scenarios that may arise throughout their professional journeys (Busch, J.R.; Lundemose, S.B.; Lynnerup, N.; Jacobsen, C.; Jorgensen, M.B.; Banner, J , 2019)

The implications of virtual reality (VR) in crime scene reconstruction extend beyond the confines of the investigative procedure. Additionally, it can play a vital role within the confines of the courtroom. The utilization of a virtual environment to showcase the reconstructed crime scene can enhance jurors' comprehension of the case in a more thorough manner. This visual representation facilitates the visualization of events and evidence, hence enhancing the ability to arrive at an informed conclusion. Moreover, virtual reality (VR) technology has the potential to reproduce the crime scene in a manner that allows witnesses to relive the event from their own visual perspective. This immersive experience can offer a more precise representation of their line of sight, perhaps leading to the discovery of previously unnoticed details.

The utilization of virtual reality (VR) and artificial intelligence (AI) in the process of crime scene reconstruction has a multitude of advantages. However, it is crucial to recognize and address the inherent limitations associated with this approach. The efficacy of virtual reality (VR) technology is contingent upon the precision and comprehensiveness of the data acquired from the crime scene. The presence of any omitted or erroneous data has the potential to result in an imperfect reconstruction. Hence, it is imperative for researchers to guarantee that the process of data collection is comprehensive and precise (Shelmerdine, S.C.; Hutchinson, J.C.; Arthurs, O.J.; Sebire, N.J , 2020)

After the 3D laser scan is transferred to a computer, it can be transformed into a three-dimensional representation of the crime scene by utilizing computer aided drawing (CAD) software. The laser scan has the capability to be perceived as a virtual "tour" of the crime scene through the utilization of software such as IC Crime, which has been developed by North Carolina State University. The jury has the capability to virtually navigate through the entirety of a crime scene, observing every aspect of the room, building, or environment. This

immersive experience allows them to perceive the situation from a first-person perspective, akin to the detectives and forensic technicians who initially conducted the investigation. From a practical standpoint, it might be argued that a jury's examination of crime scene reconstruction bears resemblance to their interaction with a first-person video game, such as Doom or Call of Duty (Schwendener, N.; Jackowski, C.; Schuster, F.; Persson, A.; Warntjes, M.J.; Zech, W , 2017)

Currently, the majority of judges are presented with visual representations of crime scenes in the form of static images. On certain occasions, a jury may be presented with a video recording depicting a comprehensive exploration of the crime scene. However, through the utilization of a 360-degree video or a virtual tour, individuals such as forensic professionals, attorneys, and juries are afforded the opportunity to observe the crime scene from a comprehensive range of perspectives. The capacity to observe a crime or incident scene from many perspectives enables judges to have a comprehensive understanding of the occurrences. Consequently, this facilitates a more precise evaluation and assessment of eyewitness testimonies (Berger, C.; Bauer, M.; Wittig, H.; Scheurer, E.; Lenz, C , 2022)

Empower the judge to make a decision. Assuming the presence of an eyewitness, it is asserted that the individual in question claims to have observed the defendant engaging in an assault against the victim from their vantage point. The utilization of virtual reality technology in recreating crime scenes will afford the jury the opportunity to visually see the precise location of the incident, including the vantage point occupied by the eyewitness. By doing an analysis of the eyewitness's vantage point in relation to the incident, the jury is able to ascertain the visual observations made by the eyewitness. The reconstruction of the crime scene has the potential to unveil the possibility that the eyewitness's line of sight was obstructed, or alternatively, that the eyewitness had a clear view of the events that transpired. In both instances, the reconstruction of the crime scene would be highly advantageous in such a situation (Jakobsen, L.S.; Lundemose, S.; Banner, J.; Lynnerup, N.; Jacobsen, C, 2016)

By employing modern technologies such as Virtual Reality, 3D Laser Scanners, and computer-aided design (CAD) programs, the process of crime scene reconstruction has achieved remarkable precision in recreating the scene. Moreover, these advancements allow members of a jury to virtually enter the crime scene and fully immerse themselves in the investigator's perspective, thereby enhancing their understanding of the crime scene. The implementation of this technology is expected to significantly influence the jury's ability to arrive at impartial judgments (Ebert, L.C.; Dobay, A.; Franckenberg, S.; Thali, M.J.; Decker, S.; Ford, J, 2022)

On the first day of March in the year 2023, consider a hypothetical scenario whereby a judicial entity possesses the capability to see the occurrence of a homicide through the utilization of a virtual reality (VR) headset, alongside the acquisition and analysis of data extracted from the deceased individual's body. The utilization of postmortem imaging by radiologists and forensic professionals in Switzerland enables the recreation of trauma mechanisms and crime scenes within the context of legal proceedings, presenting a tangible reality rather than a fictional portrayal reminiscent of futuristic science fiction films (Zhang, M , 2022)

Two instances in Switzerland have employed this technique. The initial incident, which has already been concluded, pertained to a Swiss individual who committed the act of homicide against his spouse within the confines of their residence's toilet. The individual who passed just a few months ago while incarcerated had initially made an attempt on his wife's life several years prior in Mallorca. This endeavor involved using his vehicle to forcefully collide with her as she exited their residence, resulting in her being pressed against a wall. The endeavor proved unsuccessful, and the information obtained from forensic computed tomography (CT) scans of the body was utilized to reconstruct the specific elements of the previous assault in an effort to understand the sequence of events.

Virtually reconstructed crime scenes based on real 3D virtual autopsy data put defendants, lawyers, and judges at the scene of a crime with 3D glasses.
https://www.auntminnieeurope.com/index.aspx?sec=ser&sub=def&pag=dis&ItemID=623669

According to Dr. Michael Thai, the director of the Institute of Forensic Medicine at the University of Zurich, it was observed that the wife experienced amnesia subsequent to the car incident. Additionally, the husband provided a statement to the police asserting that she had fallen from the first floor of their residence. Nevertheless, the utilization of imaging techniques and forensic analysis within the crime scene environment through the employment of 3D glasses.

The utilization of three-dimensional (3D) virtual autopsy data to virtually rebuild crime scenes has the potential to immerse defendants, lawyers, and judges into the context of the crime through the use of 3D glasses.

This case unequivocally illustrated the value and legitimacy of employing postmortem imaging for 3D reconstruction, dispelling any notion that it is merely a superficial or trivial novelty.

5-2-Negative aspects of using virtual reality

1-The use of 360° pictures may lead to a scenario in which the user perceives a disparity in elevation compared to their customary experience, owing to the height of the camera tripod. Consequently, the presence of unforeseen and perceived visual stimuli may potentially elicit motion sickness, thereby posing a potential danger of diminishing the overall user experience. The elevation of the set may also heighten the potential for diminishing the perception of reality (Grabherr, S.; Baumann, P.; Minoiu, C.; Fahrni, S.; Mangin, P ,2016)

2-The user's ability to navigate within the virtual environment is constrained by predetermined placements and orientations that are determined by the precise location and method used to capture the 360° pictures. The user is afforded the freedom to see their surroundings in whatever manner they like, as 360° images provide a greater amount of spatial and comprehensive data compared to conventional photographs. Nevertheless, the aforementioned theme is not fully realized. Due to the inherent limitations of the user's ability to navigate the crime

presented a contrasting narrative, ultimately leading to the conviction of the individual responsible for the murder of his spouse, with the motive being the acquisition of a substantial life insurance payout. The ongoing Swiss lawsuit involves the utilization of virtual reality reconstruction (Norberti, N.; Tonelli, P.; Giaconi, C.; Nardi, C.; Focardi, M.; Nesi, G.; Miele, V.; Colagrande, S, 2019)

The use of virtually reconstructed crime scenes, derived from authentic 3D virtual autopsy data, enables the immersion of defendants, lawyers, and judges .

scene, their movement is restricted to jumping between pre-existing photographs, so constraining their freedom of movement and views. Given the user's ability to subjectively position themselves at the crime scene for an indefinite duration and the encompassing nature of the 360° photograph, there is a constraint on the duration of time that can be spent within the immersive virtual crime scene while maintaining a comprehensive perspective. Given that virtual environments (VE) consist of 360° pictures, they encounter similar issues as traditional photographs. For example, it is probable that the comprehension of depth and volume can also be observed in the context of 360° photographs. One possible enhancement to consider is the inclusion of distance markers within the photographs or the substitution of the photographs with a laser scanned point cloud. This alternative approach would allow for unrestricted mobility and teleportation using the HTC Vive9. The utilization of a point cloud also resolves the aforementioned concern with the camera's elevation, as the Vive headset from HTC (HTC VIVE) enables users to experience immersion at their own individual height within a three-dimensional environment. The utilization of point clouds in virtual reality (VR) has the potential to address the issue of spatial information loss that arises from displaying point clouds or other three-dimensional (3D) models on a two-dimensional (2D) surface with a predetermined viewpoint. Point clouds are widely recognized as the most accurate and dependable technique for the purpose of documenting and visualizing three-dimensional (3D) objects. They can be regarded as virtual representations that effectively preserve evidence (Aalders, M.C.; Adolphi, N.L.; Daly, B.; Davis, G.G.; de Boer, H.H.; Decker, S.J.; Dempers, J.J.; Ford, J.; Gerrard, C.Y.; Hatch, G.M , 2017)

3-Point clouds have the potential to address the matter of legal certainty as well. Nevertheless, a significant issue arises in terms of user experience when incorporating a point cloud into virtual reality, as it creates the illusion of solidity when observed from a distance, but seems increasingly sparse and fragmented upon closer examination.

To address this matter, it may be beneficial to employ an alternative scanning methodology that involves the utilization of medium to long range scanners for capturing broader areas, while employing close-ranged scanners to focus on the intricate features of the crime scene. By implementing this approach, the level of detail in a point cloud can be enhanced, resulting in a reduction of its "dissolved" appearance as it approaches close-range scanned parts. Point clouds can be estimated and reconstructed as surfaces using methods such as triangle meshing. However, this may lead to a rather inaccurate specialized depiction (Kerbacher, S.; Pfeifer, M.; Webb, B.; Riener-Hofer, R , 2017)

Based on discussions with forensic experts at the National Forensic Center (NFC), the process of generating a meshed point cloud entails significant manual effort and has the potential for spatial misrepresentation. The avoidance of excessive misrepresentation is crucial in order to mitigate the potential reduction in the perception of realism. One potential method for developing an optimal virtual environment could involve integrating laser scanning and photogrammetry techniques. Irrespective of the selected methodology for crime scene visualization (Villa, C.; Olsen, K.B.; Hansen, S.H , 2017)

Conclusion

In conclusion, the integration of Virtual Reality technology in Crime Scene Investigation shows promise for enhancing the investigative process. The investigator will have the opportunity to mimic the crime scene through the use of virtual reality technology. This will enable the investigator to revisit the scene. It would be necessary for both the judge and prosecutor to attend the crime scene. There is no requirement for individuals to engage in physical visits, as they have the option to utilize Virtual Reality simulations. By implementing this approach, it is possible to achieve time savings and expedite the resolution of cases.

The utilization of virtual reality technology in crime scene investigation has proven to be successful in various countries. In order to enhance the utility of virtual reality in the context of investigative

procedures, it is imperative to adhere to specific methods or processes.

The novel approach of VR and polygraph application was proposed within the paper. Nonetheless the research is in the beginning phase. Software and hardware accessory, which is necessary for further evaluation were chosen and should be available soon. That is one of reasons, why this study is rather theoretical. Deeper practical evaluation of methods described will be then possible. Nevertheless, background information required for further research were summarized and the evaluation criteria of existing methods were proposed. According to this study the next research phase could start by executing empirical based steps.

The use of artificial intelligence (AI) algorithms in the process of crime scene reconstruction gives rise to ethical considerations. The utilization of algorithms for the purpose of analyzing and interpreting evidence brings the potential for bias and inaccuracies. The use of caution and rigorous evaluation of AI algorithm-generated outcomes is crucial for forensic specialists.

In summary, the integration of virtual reality and artificial intelligence is revolutionizing the domain of crime scene reconstruction. The utilization of this novel technology enables investigators to simulate crime scenes within a digital realm, so augmenting their capacity to scrutinize and comprehend evidentiary materials. Virtual reality (VR) technology provides significant training prospects for forensic specialists and can be advantageous in the context of courtroom presentations. Nevertheless, it is crucial to acknowledge the constraints and ethical implications linked to the utilization of virtual reality (VR) and artificial intelligence (AI) within this particular domain. In light of ongoing technological advancements, it is imperative for forensic practitioners to effectively assimilate and embrace these novel tools in order to enhance the precision and efficacy of criminal inquiries.

It is of the greatest significance to avoid ignoring the myriad of problems that are inherent in the process of 3D reconstruction of hypothetical scenarios. One aspect of crime scene analysis involves the presentation of an objective visualization, such as through the use of 3D visualization techniques. Additionally, the investigation and testing of various scenarios, known as 3D reconstruction, is another important component of this process. The utilization of three-dimensional reconstruction in hypothetical scenarios, which involves the virtual simulation of event dynamics, holds considerable sway and has the potential to affect the interpretation of objective information. The presence of subconscious prejudices has the ability to influence the outcome of a jury's decision. It is imperative to possess an understanding of these problems and to implement strategies in order to alleviate any possible biases or unwarranted impact when interpreting 3D visualizations and simulations within the context of forensic investigations. A precarious scenario may arise when the "objective assessment" of a crime scene relies on many results that have been subject to various interpretations, maybe by distinct specialists. The potential consequence of this situation is that it could impede the impartiality of the proceedings, leading to the potential for biased interpretations of circumstances that may favor one party over the other within a legal context. The scenarios that are subjected to testing should possess the capability to accurately represent many "realities" and sequences of events. This is because determining the proper or most realistic "reality" can often be a challenging task.

It is highly probable that virtual reality will emerge as a potent instrument in the context of investigative interviews. This technology enables investigators to facilitate witnesses' engagement with virtual renditions of an incident. Through the utilization of a fully immersive environment, investigators are able to acquire a greater depth of understanding regarding the events in question compared to conventional methods of interrogation.

Virtual reality (VR) has the potential to produce superior outcomes compared to conventional in-person interactions. Virtual interviews offer numerous advantages, such as reduced intimidation experienced by witnesses, enhanced recollection abilities, and potentially heightened accuracy.

Recommendations

1-Extensive training is necessary for police officers to effectively perform their duties. Virtual reality (VR) technology offers a simulated and secure environment wherein law enforcement agents can engage in various scenarios and hone their skills. Learning in a virtual environment eliminates the potential safety hazards that rookie police officers and the general public may encounter. This technology is now being effectively utilized within military applications.

Virtual reality (VR) training facilitates the enhancement of officers' familiarity with various categories of high-risk scenarios. This encompasses several skills like as effectively addressing active shooter incidents, employing de-escalation techniques in high-pressure scenarios, doing thorough searches, and appropriately restraining individuals through the use of handcuffs. Several prevalent use of virtual reality (VR) technology in the context of police training encompass:

Engage in the cultivation of decision-making abilities within realistic contexts.

Gain an understanding of the subjective experience of encountering an individual who possesses a weapon and intends to commit a criminal act.

Enhancing tactical decision-making in high-pressure situations.

Acquire self-assurance and cultivate forceful behavior.

Acquire the knowledge and skills necessary to effectively mitigate high-risk situations via the implementation of de-escalation techniques.

Performance feedback is provided to the participant following each simulation.

The implementation of tailored simulations to cater to the specific requirements of each department has been a valuable experiential endeavor.

https://www.youtube.com/watch?v=Iz7k2THJnLE

2-In the domain of virtual reality simulations designed for police negotiations, instructors possess a wide range of possibilities in terms of scenario creation. These scenarios encompass diverse situations such as negotiating with armed individuals involved in robbery or drug-related activities, as well as effectively managing incidents including hostage situations or active shooters. Educators possess the ability to tailor scenarios according to the particular requirements or obstacles that their students may encounter during practical experiences.

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