Proposed Adoption of Virtual Reality Framework in Digital Forensics Curriculum

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Abstract

Recently, the field of digital forensics (DF) has undergone a significant evolution. The need for comprehensive digital forensics education has therefore become increasingly important, requiring students to have a clear understanding of key terminologies and practical applications in real-world scenarios. In this study, we proposed the use of a virtual reality (VR) framework as an innovative approach to enhance traditional teaching methods in digital forensics education by building photogrammetric illustrations of scenario-based VR environments on some of the suggested areas of digital forensics where VR can be applied to simulate the benefits of VR as an alternative method of gaining hands-on experience digital forensics investigations for institutions with limited budgets. We also identified the key digital forensics topics suitable for applying the proposed VR framework from the curricula of various universities of U.S.A through an extensive literature survey. The article encourages that these labs should cover common digital forensics topics by incorporating our virtual reality framework, providing students with realistic and interactive learning experiences. Furthermore, we aim to refine existing frameworks to focus on education, digital forensics, and virtual reality. This approach also has the potential to address the shortage of practical training in digital forensics education, as VR technology can provide students with a safe and controlled environment to experiment with different scenarios. By providing students with interactive and immersive learning experience, we can better prepare the next generation of digital forensics professionals to tackle the challenges of tomorrow's digital world.

Keywords: Digital forensics, Virtual reality, Education, Immersive learning, Cybersecurity

1. INTRODUCTION

Digital Forensics (DF) can be defined as "the application of computer science and investigative procedures for a legal purpose involving the analysis of digital evidence after proper search authority, chain of custody, validation with mathematics, use of validated tools, repeatability, reporting, and possible expert presentation" (Sammons, J., 2012). The incorporation of immersive simulations, such as virtual reality (VR), into educational settings is becoming increasingly popular in higher education as a way to enhance student learning outcomes, particularly in undergraduate courses and laboratory safety training. VR simulations offer a number of benefits, including hands-on, interactive learning experiences, and a safe and controlled environment for students to practice and apply theoretical concepts. Research has suggested that VR simulations can improve students' engagement, motivation, and retention of information, creativity, and critical thinking skills. Overall, VR technology in education has the potential to revolutionize the way students learn and prepare them for their future careers (Hodgson et al., 2019; Makransky et al., 2019).

VR has been used to increase learning outcomes amongst teachers and students in training within other disciplines, such as medicine, sports, entertainment, marketing, and engineering, but not as much in digital forensics training (Billingsley et al., 2019). The primary objective of this article is to identify and analyze existing frameworks, and to develop a comprehensive approach for incorporating VR technology in digital forensics education. This study provides a systematic solution for addressing challenges such as declining interest in certain academic disciplines and a lack of interactive and hands-on learning opportunities. It will help in evaluating the potential benefits of VR technology in digital forensics education such as improved engagement, motivation, and retention of information, problem-solving skills, and creativity. Additionally, the study can help in investigating the potential of VR technology to create safe and controlled environments for students to practice and apply theoretical concepts, thereby reducing the risk of errors or accidents in real-world scenarios. Overall, recent advances aim to contribute to the development of new and innovative approaches for teaching digital forensics through the use of VR technology (Bulut et al., 2019; Gupta et al., 2022).

Digital forensics needs more professionals and individuals willing to adopt newer technologies in learning. As there are not enough minorities and students from low-income families in "STEM" (science, technology, engineering, and mathematics (Funk & Parker, 2018), our research could positively influence changes to the narrative by attracting undergraduate students to the discipline. Also, digital forensics may be relatively new compared to cybersecurity and computer science. However, it has many use case scenarios in multiple ways that we will explore further in this paper.

2. LITERATURE REVIEW

Virtual Reality Application in Learning

It should be noted that since the acceptance of immersive virtual reality (I-VR), as an educational method when it comes to education, there is a challenge raised on the conceptual explanation of what actually makes a learning environment (Hamilton et al., 2021). There has been the placement of high-fidelity graphics together with immersive content through the use of head-mounted-displays (HMD) that have given the opportunity to the students to explore and cover a number of intricated subjects in a manner that was not possible when the old teaching approaches were used. Regardless of these tremendous breakthroughs, what has been observed is that research that focuses on educational outcomes, characteristics of intervention together with assessment measures that are associated with I-IR use have been lacking or in other words, they have been limited in the learning arena (Hamilton et al., 2021).

The study conducted by Hamilton et al. (2021) happens to contain learning outcomes, which are quantitative in nature, employing HMD based I-IR which was compared alongside pedagogical methods that are less immersive, like personal computers and slideshows. It should be noted, that when it comes to Virtual reality (VR) technology and its impact within the teacher education programs, it has been tremendously praised as it has a promise in enriching the sector with numerous learning opportunities (Makransky et al., 2019).

As such, another study was conducted by Billingsley et al., (2019) that focused on investigating some ways that immersive virtual reality has been implemented in teacher-training programs. In this case, it should be noted that the systematic review in question was focused on eight studies that covered immersive VR being utilized in the increase of learning opportunities during courses that were preparing pre-service teachers or in-service teachers who

were taking advanced coursework in education. The various ways that the studies were evaluated according to Billingsley et al., (2019), were participation description, description of the intervention and purpose of the study, study methodology, dependent variable, and outcomes of the study. Something worth noting is that after careful evaluation and analysis on the studies, the conclusion was that there was some efficacy on the use of immersive VR to prepare teachers and this confirms that these types of technologies can indeed enrich and therefore enhance learning opportunities for teachers in the future (Billingsley et al., 2019).

However, it was observed that the research in this area is lacking. Jisc, which happens to be the technology provider to the sector that is tasked with operating a membership organization for colleges and universities, has gone ahead and published a study that it undertook and from the analysis, 82% of the 101 respondents that took part, who were from higher education backgrounds, were keen on the process of immersing technologies (Say, 2019). On the other hand, 49% reported that they were very interested in the idea. The nature of the support seen was more so because there is a view that technology is able to provide good and quality experiential form of learning for anyone involved (Say, 2019). Through this, the study respondents were able to get what they cannot in a traditional classroom. Additionally, it should be noted that interest is high, because of the fact there is plenty of untapped potential within organizations. Moreover, from the surveys collected in the latter study, the respondents were keen to suggest that they were able to encourage innovative approaches, the teaching, acquisition, and retention of a wide array of skills. Regardless of all this, something that is clear is that AR and VR are already in use quite significantly, approximately 96% of the universities and 79% of the colleges (Say, 2019). However, it is usually in some two or one departments or faculties, 58% and 43% for the universities and colleges (Say, 2019). In line with this, about a third of each are either concentrating on making use of their own resources and content or utilizing their own version or rather mixed model that happens to combine with collaborations from other proclaimed and willing organizations. To note, a small number like 11% in higher education and 5% in further education happen to buy content and resources from external mediums (Say, 2019).

Existing Virtual Reality Frameworks

Considering the fact that the collection of most of the educational data happens to be associated with web-based platforms, the likes of learning management systems, because of the fact that they offer students direct access to students' data with minimal effort to say the least, there is a presentation of a four-dimensional theoretical framework by Christopoilos et al. (2020) for virtual reality- supported instruction. This four-dimensional framework incorporates learning analytic methods while taking into account the many facets that the learning process exhibits (technology, pedagogy, psychology), as shown in Figure 1. In addition to this there is a proposed collection of structural elements that may be used in combination with a prototype system of learning (Christopoulos et al., 2020). Given the crucial need of the world to come to terms that entrepreneurship is what will save our economy, there has been the aspect of coming up with effective entrepreneurship educational frameworks along with training programs (Grivokostopoulou et al., 2019).

Figure 1: Existing Four-dimensional Framework

Another study, as reported by Grivokostopoulou et al. (2019), presented an educational entrepreneurship environment which primarily focuses on understanding 3D virtual worlds. As such, it can be noted that novel 3D VR technologies were used to provide immersive and effective learning experience (Grivokostopoulou et al., 2019). Moreover, the educational 3D VR environment happens to utilize pedagogical methods that are based on the principles of gamification and thus, letting students to be able to learn in immersive ways, incorporating game-based activities on real-world challenges that are present in business settings (Grivokostopoulou et al., 2019). These game-based activities are able to allow the students to acquire the necessary skills that will assist them deal with everyday obstacles on their bright entrepreneurial pathways (Grivokostopoulou et al., 2019).

It should be noted that virtual reality frameworks have made considerable headways when it comes to the engineering sector (Bulut et al., 2020). Mechanical engineers have been blossoming and enjoying a high reputation since the happening of the industrial revolution (Bulut et al., 2020).

Regardless of this, there has been a considerable and significant drop in the number of students applying to take part in mechanical engineering, something which has raised alarms, and this has necessitated a turnaround in the normal working of things. Most importantly, what has been provided as the reason, or rather been speculated upon, is the solid foundation of the green movement which has resulted in less mechanical things consuming oil, petrol, or diesel to be cut back, when it comes to production (Bulut et al., 2020).

For the purpose of raising the morale of the students and making sure that they enroll as much as they did before, there has been a proposal and an application has been created that happens to offer gamified engineering education for the mechanical engineering students in a way that will show them how and why mechanical engineering leads to a sustainable and digital world (Bulut et al., 2020). It should be noted that the content on the app is offered in a superficial manner and as such, invoke curiosity among the mechanical engineering students (Bulut et al., 2020).

Learning Outcomes

It can be noted that the presentation of the four-dimensional framework for virtual reality-supported instruction being intertwined with elements, which may be possibly placed in a prototype system of learning analytics, are predictable to produce outcomes that are likely to mostly help practitioners where they may be able to maximize on the possibility of their interventions. (Christopoulos et al., 2020). On another front, we are presented with the study whereby there is the development and design of an immersive VR experience in order to teach Digital Forensics where there was the use of digital devices (Hassenfeldt, Jacques, & Baggili, 2020).

Additionally, another group was provided with a hands-on physical experience where they had to do the work physically in a laboratory. During the study, there was the collection of pre- and post-results so as to be able to conduct a robust assessment of the group of students on their knowledge of Digital Forensics (Hassenfeldt et al., 2020). It can be observed that there were no significant differences of the students, from the immersive VR and those that did all the work in the real word. However, what was noted was the faster completion times by the students that made use of the immersive VR, and this showed that VR environments are more efficient because of their nature to be spun programmatically with little to no downtime (Hassenfeldt et al., 2020).

Therefore, funding in this sector needs to be done and more minds need to spare time to try and research this sector as more needs to be done and time waits for no one.

3. METHODOLOGY

Data Collection

The first step was to identify the key digital forensics topics that need to be covered in the scenario-based laboratories. This involved a review of existing literature, consultation with experts in the field, and analysis of current industry trends. Dafoulas and Neilson (2019) reviewed twenty-three American universities and the modules offered in DF by these schools. Based on their paper, we were able to select certain topics. In digital forensics, there are numerous topics at different academic and industry levels, but for the purpose of this paper, we wanted to focus on the most common topics most DF students have to study in a typical course curriculum. Our focus was on US based universities and Focus (2023) provided us with an accurate description of some schools that offer DF under various names.

Study Design

Research Question

For this paper, we will be addressing this research question:

- ***how virtual reality environment can be set up in universities with limited budgets to improve hands-on learning experience?***

Proposed VR Framework

Our proposed framework was designed to contain several major steps that function in conjunction with a DF related concept in a typical DF curriculum.

Building Photogrammetric illustrations of scenario-based VR environments

Furthermore, we built several illustrations of VR simulations for some of the common topics and areas dealing in digital forensics. These scenario-based environments were designed keeping in mind integration of the proposed VR framework into DF learning.

4. RESULTS

Common Topics in DF

We looked at several use cases where VR application can be implemented in a Digital Forensics program. We reviewed the modules that contain elements of hands-on experience, requires an in- depth knowledge of concepts, requires experimental testing that would otherwise be financially profligate, especially if the institution cannot afford the budget. Figure 2 and Table I show the most common topics and modules studied by students in a typical DF curriculum across multiple universities in the USA, with "Cybersecurity Foundations" being the most common module. "Cybersecurity Foundations" was the part of curriculum in 13 schools, followed by "Legal and Ethics for cybersecurity/digital forensics" being taught in 11 schools. "Digital Forensics Analysis" was also quite a common module being studied in 9 U.S schools.

DF Modules in US programs	Number of schools offering the course
Legal and Ethics for cybersecurity/digital forensics	11
Cybersecurity Foundations	13
Digital Evidence Management	7
Crime Scene Investigations	8
Internet of Things	1
Network security	6
Information security and risk management	7
Incident Response	7
Digital Forensics Analysis	9
Cyber warfare and Cyber terrorism	5
Ethical hacking and Penetration testing	4
Introduction to digital forensics	4
Law and high technology crime	2
Data Analysis and Visualization	1

Table 1: Digital Forensics Modules Offered In American Schools

The least common ones were "Internet of Things," Data Analysis and Visualization" and "Law and High Technology Crime", occurring only in 1 and 2 schools respectively. We suggest that the topics/modules mentioned in Figure 2 and Table 1 should be implemented because they include practical aspects that cannot be fully understood from solely a theoretical perspective, rather than from an immersive simulation.

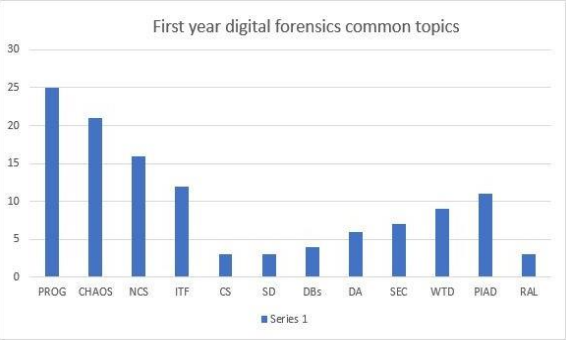

Figure 2: Common Topics in DF Curricula
(PROG: Programming, CHAOS: Computer Hardware, Architecture and Operating Systems, NCS: Networking and computing skills, ITF/DFIR: Introduction to Forensics/
Digital Forensics and Incident Response, CS: Computer Science, SD: Software Development, DBs: Databases, DA: Data Analysis, SEC: Security, WTD: Web technologies and development, PIAD: Professional Issues and Development, RAL: Regulatory and Law)

Proposed VR Framework Integrating DF curricula

Steps of the framework

1.Development of scenario-based laboratories: Once the identification of the most significant DF topics, the next step would be to develop scenario-based laboratories within a virtual environment using the Unity gaming engine. The scenarios should be designed to cover the selected topics and provide students with realistic and interactive learning experiences.

2.Selection of participants: The study would involve selecting a sample of students enrolled in a digital forensics program at a university or college. Participants should be selected based on their willingness to participate in the study and their level of expertise in digital forensics.

3.Pre-test assessment: Before the VR-based digital forensics labs are introduced, a pre-test assessment should be conducted to establish a baseline understanding of the participants' knowledge of digital forensics.

4.Introduction of VR-based digital forensics labs: The VR-based digital forensics labs should be introduced to the participants, and they should

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be provided with instructions on how to use the VR technology and navigate the scenarios.

5.Post-test assessment: After the participants have completed the VR-based digital forensics labs, a post-test assessment should be conducted to measure their comprehension and engagement with the subject matter. Thisshould be compared to the pre-test results to determine the effectiveness of the VR-based approach.

6.Analysis of results: The data collected from the pre-test and post-test assessments should be analyzed to determine if the VR-based approach improved participants' comprehension and engagement with digital forensics. This analysis should also identify any areas where the approach could be improved or expanded.

7.Conclusion and recommendations: Based on the results of the analysis, the study should conclude with recommendations for the use of VR-based technology in digital forensics education and potential areas for further research.
Figure 3 shows the VR framework proposed in this study.

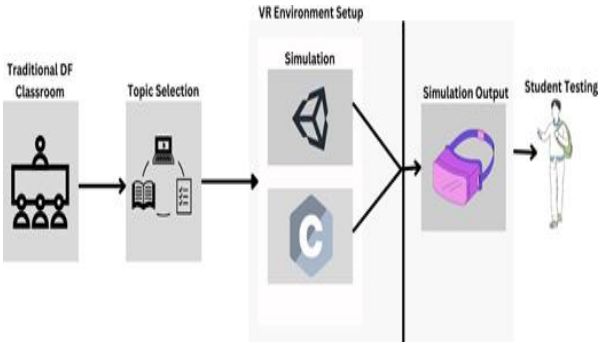

Figure 3: Our Proposed VR Framework

Designing Photogrammetric Scenario-based VR Environments

During our experimentation, we were able to build some scenarios suitable for DF learning. From our Table 1,we know that introduction to forensics is a common topic, so another way this can be incorporated is by including a virtual space of how and what can be contained in a digital forensics' laboratory. As shown in Figure 4, the DF lab contains storage which is important in securing and preserving evidence and monitoring chain of custody forms.

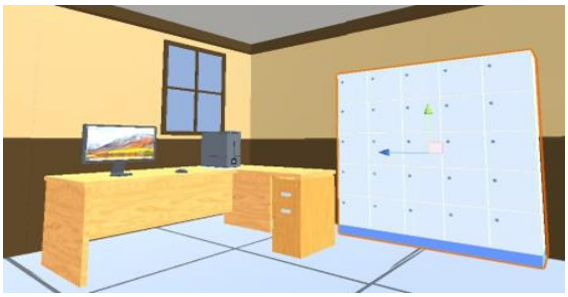

Figure 4: A Digital Forensics Lab

Figure 5: A Server with Multiple Workstations

Knowledge of hardware and software are both necessary in DF. In a networking module, types of operating systems, networking software and interfaces, command lines and network architecture are some important things to know. In Figure 5, we created a server in a virtual reality space that can beused to run various network attacks simulations.

Crime scene investigations are necessary and would teach the foundational steps in acquiring, handling and documenting evidence. The use of write blockers to prevent data from being rewritten into existing digital evidence is important. Also, in a typical crime scene setting, DF professionals ought to know the importance of warrants and what they explicitly entail. In Figure 6, we provide electronic devices in a virtual space to simulate steps taken to achieve a successful forensics analysis.

Figure 6: A Typical Example of a Scene

As aspiring DF experts, there is need to know the legal and ethical aspects of the discipline. Knowledge of the federal rulesof civil procedures (FRCP) and federal rules of evidence are important and beneficial. Figure 7, infers the importance of legal and ethics, working with law enforcement.

Figure 7: An Officer of the Law

5. DISCUSSION

VR Use-Case in Digital Forensics

We believe some of the main topics in DF that we found both relevant to DF and common to the field according to our results, can be some experimental use- case examples of how we will be implementing VR in the DF curriculum.

1) Regulatory and law: As future DF specialists, students in this career path ought to have an insight on the legal and ethics of the profession including electronic-discovery (eDiscovery) and how it relates to digital forensics. Also, as they could be expert witnesses to someday, they need to know first-hand how to act, what to say and how to speak without prejudice to either defense or prosecution. They need to know how a courtroom looks like, they also need to know the federal rules relating to evidence acquisition, civil and criminal procedures. High technology crimes that use digital and electronically based technology can also be studied from either an attacker or a defender's perspective. With specially built VR environments, we are certain that the immersive experience would stimulate retention, which is decent for testing out mock trials and expert witness testimonies (Hughes et al., 2015).

2) Security: Cyber warfare and cyber forensics are some important aspects of security within the DF module that requires-special studies and trainings. Network security, also

another aspect of security is a module that requires expertise on and as such there will be a need for several simulations on best practices, mitigating and prevention of network attacks on small to large scale organizations. With VR technology, simulations can include network mapping to simulate concepts like single-point-of-failure on network maps, Zero-day attacks scenarios, architecture and design weaknesses (Kallberg and Thuraisingham, 2012).

3) Introduction to Forensics and Digital Forensics and Incident Response: As a foundational course, it includes the basic knowledge of digital evidence management, how to process a crime scene investigation, acquiring, handling, and preserving evidence. Imaging digital media devices to forensically analyze at a later time and steps to incident response which may include, preparation, detection, analysis, containment, eradication, and recovery. Elements within a simulated VR environment can be designed to contain simulated crime scenes with steps on processing the scene. It can also be designed to guide DF students on evidence management, concepts of how honeypot works in attracting unsuspecting bad threat actors and also virtually implementing and testing the security strength of firewalls for vulnerabilities Itodo et al., 2021).

4) *Data Analysis:* Data analysis is a very integral aspect of a DF specialist's career. The ability to gather data, refine the data and interpret the content of the data logically is a great skill that many industry experts and academicians strive to possess. Data virtualization can be done within a VR space to guide students in accurately examining data based on content- types, categories, and results. What makes VR incredibly unique is that the students get to be in an immersive space that allows them to interact with these data virtualization (Ozcan et al., 2020).

5) *Networking and Computing skills*: DF is applicable in almost every aspect of technology

that contains digital data and electronic evidence and even more applicable with the concept of Internet of Things (IoT). The concept of IoT describes it as a system of interrelated components communicating with each other via embedded sensors and software. VR can be useful here for a few reasons. It can be used by scanning a real model and working on that model on a virtual platform, creating a virtual replica of the real object. It saves cost as changes made in the virtual space could be implemented in real-life if it meets the purpose of its creation. This concept is called Digital Twin and it is valuable for companies trying to scale infrastructures without disrupting the flow of business (Kizilirmak et al., 2023).

VR Environmental Setup

In the environmental setup, our framework looks to build the required environment for each conceptual training using a combination of Unity gaming engine platform and the C# programming language with various open-source templates that are both user friendly and also fulfills the objective of the DF training.

Unity Game Engine: The Unity game engine uses C# as the primary scripting language. Because of this, the code written is termed as being stable and effective. In addition, it provides powerful tools that are able to make deep and engaging augmented virtual reality experiences that are able to interact with the world. It should be noted that Unity is good across all platforms and because of this factor, it is heavily liked by developers across the board. The other rival engine is Unreal game engine. Over years, because of needs in the developing community, the two game engines have become extremely useful when it comes to virtual reality. It is hard to choose one over the other because of the immense improvements that have been over the years. As a way of adopting game engine and virtual reality into an educational curriculum, what can be done is for example coming up with a VR and Game Development program which will allow students to be able to choose courses that are able to match their career goals (Ohio University, 2023). Considering that technology is more than exciting and most importantly, bringing onboard virtual reality, the students will be able to be involved in information networking systems and coding that will come in handy in solving problems and learning through virtual reality and game systems, they will be able to implement these aspects within a larger context (Ohio University, 2023).

XR Rig: It should be noted that one cannot experience a virtual reality scene without the interaction toolkits such as XR rig and OVR that make sure that the user is able to move around the virtual reality environment and have the full experience as it is intended. To make the environment even better specialty graphics cards are used together with interactable 3D material. More on the 3D interactive material, because today students want to learn things as they interact with them, it has forced content designers to come up with ways of making this possible (CIP, 2021). One major area that has been targeted is the health science sector where it has become apparent that it is quite difficult to teach anatomy and physiology courses and as a result, a number of students are not able to reach even the standard form of understanding (CIP, 2021). A majority of students who happen to find themselves having gotten some good grades and proceeded forward, have come to admit that even though they have the grades on paper, they are not that quite confident with the knowledge that they have when it comes to anatomy structures, something which is crucial for any course done within the health science sector (CIP, 2021).

Simulation Output

Virtual Reality Headset: A virtual reality headset is defined as a heads-up display (HUD) that make sure that users are able to interact with stimulated environments and in so doing, they are able to experience what is termed as a first-person view (FPV) (Thomas & David, 1992). Therefore, VR headsets tend to replace the user's natural environment with one that has virtual reality content, for example, a game, a movie or even a prerecorded 360- degree VR environment which is able to allow the user to look around and turn in the physical world. Even though VR has been around for years, traditionally, the tethered hardware has been usually expensive, and few people have been able to use them. However, currently, they are easy to wear and less expensive and this can allow them to be integrated into the education curriculum whereby students can be able to view features, for example, geographical features and even things in medicine, such as someone's anatomy and the like, and through this experience, the students can have a better understanding of what they are learning.

Limitations

The study encountered certain challenges, including compilation errors during debugging and limitations in obtaining suitable

photogrammetry scans of 3D images, these obstacles did not impede the overall success of the research. Additionally, addressing the concerns of those who may have preconceived notions about the negative effects of VR usage was an ongoing challenge. However, the research team is optimistic that the instructors will advocate for the importance of VR in improving education.

Future Outlook

In recent years, virtual reality (VR) technology has been adopted across a wide range of disciplines. In light of this trend, the proposed research aims to evaluate the effectiveness of incorporating a VR environment into the curriculum for digital forensics education.Specifically, this study aims to assess the efficiency, reliability, and quality of the VR environment through student testing in a classroom setting.

In addition to evaluating the VR environment, the proposed research also seeks to expand the scope of the study by incorporating more realistic 3D replicas of the instruments and apparatuses used in digital forensics. Furthermore, to address the limitations of physical space during simulations, the study can investigate alternative solutions for accommodating loco- motion within and outside the virtual space.

6. CONCLUSION

In conclusion, this study has demonstrated the potential for incorporating virtual reality (VR) technology into a digital forensics' curriculum by providing a VR framework and building scenario-based VR environments through photogrammetric illustrations. The research was further supported by an analysis of common topics in digital forensics programs and digital forensics modules in US-based educational institutions.

Overall, the research team believes that this study will be valuable in the training of digital forensics experts, providing an immersive and cost-effective learning experience that will improve retention and reproduction of knowledge in the field.

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