Penerbit Akademia Baru

Journal of Advanced Research in Computing and Applications

Journal homepage:
https://akademiabaru.com/submit/index.php/arca/index
ISSN: 2462-1927

Revolutionizing Virtual Reality with Generative AI: An In-Depth Review

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ARTICLE INFO

Article history:
Received 5 January 2023
Received in revised form 17 February 2023
Accepted 1 March 2023
Available online 20 March 2023

Keywords:
Virtual reality; Artificial Intelligence; New Media

ABSTRACT

This in-depth research investigates the transformational potential of generative artificial intelligence (AI) in virtual reality (VR) by methodically examining 26 papers obtained through advanced search techniques on the Scopus and JSTOR databases using the keywords "Artificial Intelligence" and "Virtual Reality." The study focuses on three major themes: immersive settings, content generation, and user interaction. Our findings show that generative AI improves VR by creating more realistic and dynamic immersive worlds, automating and personalizing content generation, and boosting user engagement with adaptive and intelligent systems. This combination of generative AI and VR promises to make substantial advances in a variety of industries, including gaming, education, training, and treatment, by creating more engaging and interactive experiences.

1. Introduction

The merger of generative artificial intelligence (AI) with virtual reality (VR) is a watershed moment in technology, with the potential to transform how consumers interact with digital surroundings [1]. As VR technology advances, the use of generative AI offers up new possibilities for creating more immersive, dynamic, and interactive experiences. This review paper, titled "Revolutionizing Virtual Reality with Generative AI: An In-Depth Review," seeks to investigate this transformational potential by conducting a thorough analysis of the existing environment and future prospects of this interdisciplinary subject.

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This study examined 26 essential papers using advanced search algorithms on the Scopus and JSTOR databases with the keywords "Artificial Intelligence" and "Virtual Reality." These articles are divided into three major categories: immersive environments, content creation, and user interaction. Each element is important for understanding how generative AI might improve VR experiences.

Generative AI can develop more realistic and flexible virtual worlds, which benefits immersive settings[2]. This technology provides dynamic and flexible settings that can adapt to human inputs, resulting in a greater sense of presence and engagement.

In content creation, generative AI automates the creation of diverse and personalized content, decreasing the need for manual development and enabling more targeted experiences[3], [4]. This capacity is especially important in domains like gaming, education, and training, where personalized material can significantly improve the user experience.

User engagement is another critical area in which generative AI has a significant impact. Using intelligent systems, generative AI may adapt to human behaviors and preferences, resulting in more natural and engaging interactions[5], [6]. This versatility is critical for applications that require a high level of user interaction and reactivity.

This analysis finishes with a discussion of the obstacles and future directions for merging generative AI and VR. Despite hopeful advances, significant challenges remain, including technical constraints, ethical concerns, and the need for additional study. Addressing these problems will allow generative AI to fully fulfill its potential in changing VR, paving the path for creative applications in a variety of disciplines.

2. Related Work

The combination of generative artificial intelligence (AI) and virtual reality (VR) has considerably increased the possibilities and uses of VR technology. According to studies, generative AI may build more realistic and dynamic virtual worlds, which improves user immersion and engagement[7,8]. Artificial intelligence systems, for example, may create intricate, lifelike virtual environments that respond to user activities. This adaptability results in a more responsive and dynamic experience, which is especially useful in gaming and training simulations, where realistic scenarios can considerably improve the effectiveness of the experience [1,9,10].

Furthermore, generative AI has increased the visual and audio quality of virtual reality situations. Advanced AI algorithms allow for the creation of high-resolution textures, realistic lighting effects, and immersive soundscapes [3,4]. These upgrades help to provide a more believable and compelling virtual experience, boosting VR's potential uses in domains such as education, healthcare, and entertainment. According to research, these enhancements not only boost user pleasure but also widen the area of VR applications [11,12].

Generative AI is especially important for automating and personalizing content generation in virtual reality. This automation eliminates the need for considerable manual development, enabling for the provision of diversified and personalized content based on users' specific needs and preferences [13]. For example, AI-driven content generation can be used to create educational modules that adjust to students' learning paces, as well as individualized virtual tours in tourism and cultural heritage protection [14,15]. This functionality ensures that consumers may obtain relevant and entertaining content.

Furthermore, generative AI's ability to create procedurally created content is noteworthy. This technology enables the on-the-fly construction of distinct and diverse virtual environments based on established parameters, reducing development time and resources [16].

Procedurally produced content ensures that consumers are exposed to new and unique content every time they interact with the VR system. This adaptability and scalability are especially useful in applications like large-scale online games and virtual social networks, where keeping users interested through new content is critical [17,18].

Generative AI has a tremendous impact on user engagement in VR. AI-powered systems may adapt to users' behaviors and preferences, resulting in more intuitive and engaging interactions. This versatility is critical for applications that demand a high level of user involvement and reactivity, such as treatment, education, and training [15,19]. For example, in therapeutic VR applications, AI can tailor scenarios to the user's emotional and physical responses, resulting in a more personalized and effective therapeutic experience [20,21].

Finally, combining generative AI and VR has enormous potential for producing more immersive, interactive, and personalized experiences. The breakthroughs in creating realistic settings, automating content generation, and improving user engagement demonstrate this technology's transformative potential [13,14]. Despite the positive discoveries, a number of hurdles remain, including technical constraints, ethical concerns, and the need for additional research. Addressing these problems is critical for fully achieving generative AI's promise to revolutionize VR and pave the way for creative applications in a variety of sectors.

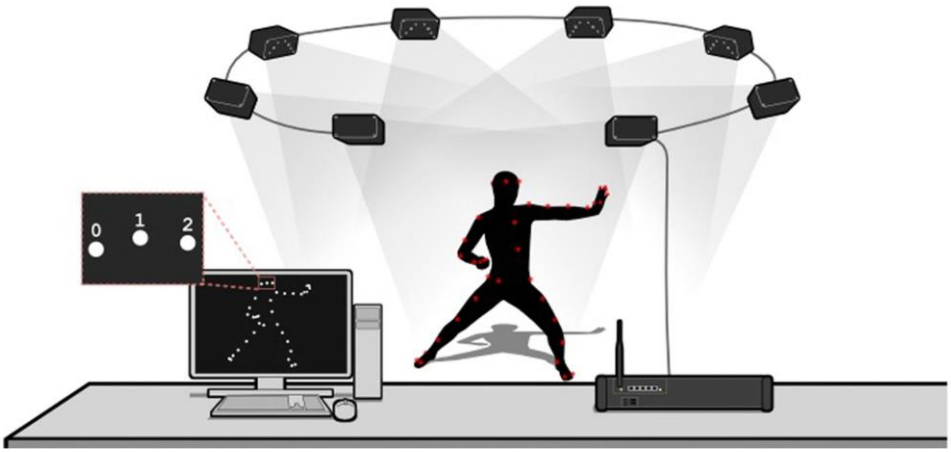

Fig. 1. Virtual reality in training artificial intelligence-based systems: a case study of fall detection [14]

3. Material and Methods

3.1 Identification

In choosing several appropriate papers for this report, the systematic review process consists of three main phases. The first step is keyword recognition and the quest for linked, similar terms based on the thesaurus, dictionaries, encyclopedia, and previous studies. Accordingly, after all the relevant keywords were decided, search strings on Scopus and JSTOR (see Table 1) database have been created. In the first step of the systematic review process, the present research work successfully retrieved 90 papers from both databases.

The identification phase involves searching for study materials relevant to the predetermined research issue. The keywords used are Gamification and advertising. Therefore, the first step was to detect keywords and search for similar, equivalent phrases in previous research. As a result, after determining all relevant phrases, search strings for the Scopus and JSTOR databases were created (see Table 1). Thus, during the first part of the advanced searching procedure, this study effectively obtained 40 publications from the databases.

Table 1
Database search

Scopus	TITLE-ABS-KEY ("Artificial Intelligent" AND "virtual reality") AND PUBYEAR > 2019 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE , "English"))
ERIC	"Artificial Intelligent" AND "virtual reality"

3.2 Screening

Duplicated papers should be excluded during the first step of screening. The first phase omitted 90 articles, while the second phase screened 50 articles based on several inclusion-and- exclusion criteria developed by researchers. Literature (research articles) was the first criterion because it is the primary source of practical information. It also includes the exclusion from the current study of publications in the form of systematic review, review, meta-analysis, meta-synthesis, book series, books, chapters, and conference proceedings. Furthermore, the review concentrated exclusively on papers written in English. It is essential to note that the schedule was chosen for a fourteen-year duration (2020–2024). In all, 40 publications based on specific parameters were excluded.

3.3 Eligibility

For the third step, known as eligibility, a total of 37 articles have been prepared. All articles titles and key content were thoroughly reviewed at this stage to ensure that the inclusion requirements were fulfilled and fit into the present study with the current research aims. Therefore, 11 reports were omitted because they were Full text excluded, due to the out of field (n=6), Title not significantly (n=3), Abstract not related on the objective of the study (n=2) based on empirical evidence. Finally, 26 articles are available for review (see Table 2).

Table 2
The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line	2020 – 2024	< 2020
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press

3.4 Data Abstraction and Analysis

One of the assessment procedures employed in this study was integrative analysis, which was used to investigate and synthesis a variety of research designs (quantitative, qualitative, and mixed methods). The competence study's purpose was to discover significant themes and subtopics. The stage of data collection was the first step in the theme's development. Figure 2 depicts how the writers methodically examined a collection of 90 articles for assertions or material relevant to the current study's issues. The authors next reviewed the most recent significant papers on Artificial intelligent and virtual reality. The methods employed in all investigations, as well as the research findings, are being looked into. Following that, the author worked with other co-authors to build themes based on the data in design thinking and creative technology education (Mohd Ekram Hashim-expert in new media, and Wan Azani Wan Mustafa in Artificial Intelligent) to determine the validity problems. The expert review phase ensures the clarity, importance and suitability of each subtheme by establishing the domain.

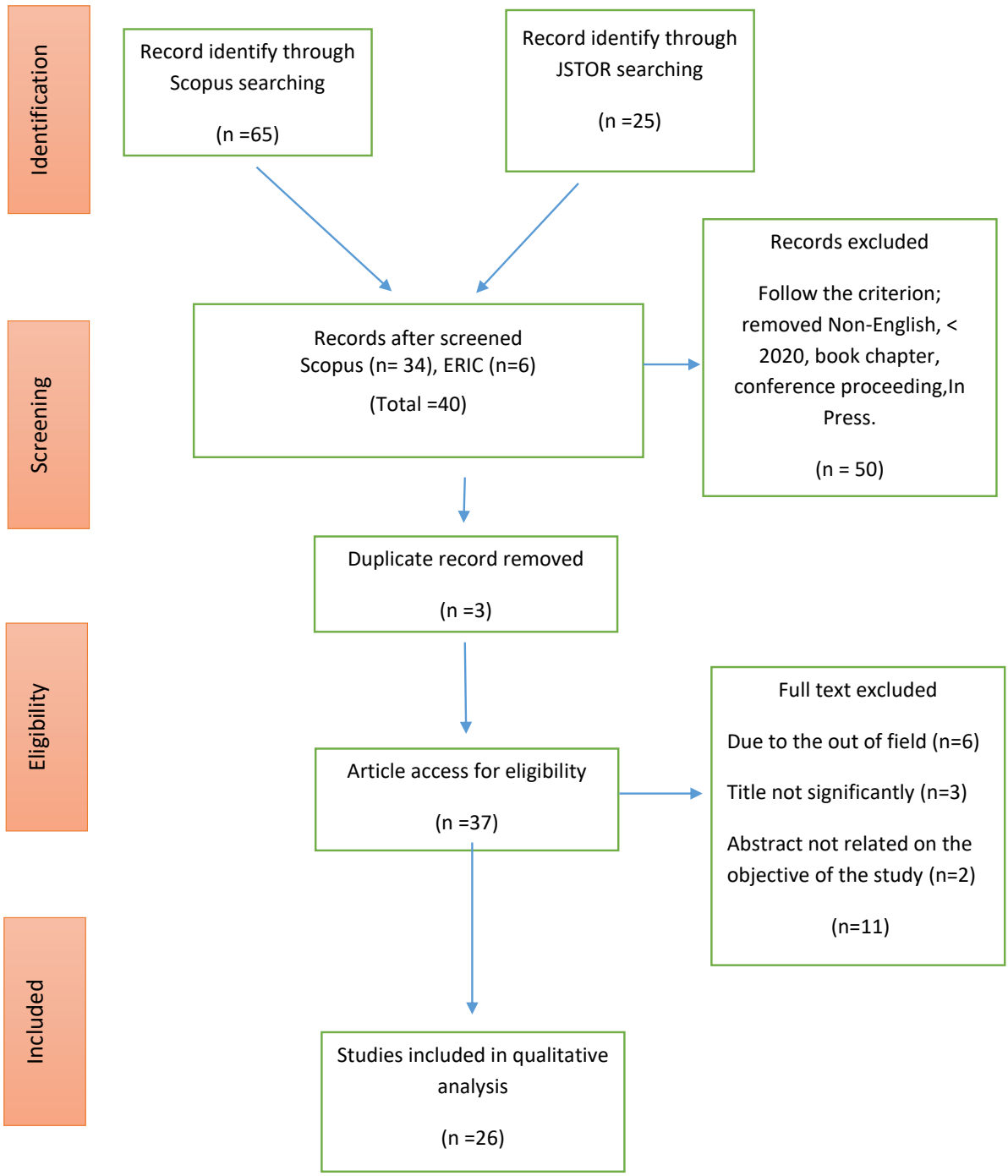

Fig. 2. Flow diagram of the proposed searching study [22]

4. Synthesis Analysis

4.1. Immersive Environments

The combination of generative AI and virtual reality is propelling substantial advances in immersive environment design. Current research is focused on generative AI's capacity to create extremely realistic and adaptive virtual spaces that improve user engagement. [18] highlight the use of AI to create complex, lifelike virtual environments that respond dynamically to human activities, resulting in a more engaging and responsive experience. This versatility is critical in applications like gaming and training simulations, where environmental realism can have a major impact on the effectiveness of the experience.

Another key feature of immersive environments is the use of artificial intelligence to improve visual and audio quality. He demonstrates how generative AI approaches can produce high-resolution textures, realistic lighting effects, and immersive soundscapes. These enhancements help to create a more believable and engaging virtual experience, making VR applications more desirable and useful in a variety of disciplines, including education, healthcare, and entertainment.

Furthermore, AI plays a critical role in automating and personalizing content development in virtual reality. This automation eliminates the need for considerable manual development, enabling for the provision of diversified and personalized content based on users' specific needs and preferences. For example,[2] show that AI-driven content generation can be used to create educational modules that adjust to students' learning paces or individualized virtual tours in tourism and cultural heritage protection. This capacity guarantees that consumers have access to relevant and entertaining content, which improves the overall immersive experience.

The capacity of generative AI to generate procedurally generated content contributes significantly to the enhancement of immersive experiences. [14] explain how this technique enables the on-the-fly construction of new and diverse virtual environments based on established parameters, reducing development time and resources. Procedurally produced content ensures that consumers are exposed to new and unique content every time they interact with the VR system. This adaptability and scalability are especially useful in applications like large-scale online games and virtual social networks, where keeping users engaged through new content is critical.

In the context of user interaction, generative AI can learn from user behaviors and preferences, resulting in more intuitive and engaging interactions. This versatility is critical for applications that demand a high level of user involvement and reactivity, such as treatment, education, and training. For example, [13] demonstrate that in therapeutic VR applications, AI may adapt settings based on the user's emotional and physical responses, resulting in a more personalized and successful therapeutic experience.

One major advancement is the construction of an Immersive Virtual Reality Training System for children with Autism Spectrum Disorder (ASD), as noted by [12]. This system uses generative AI to tailor virtual trainer behavior to users' moods and behaviors, thereby improving social interaction and communication abilities. This technology uses AI algorithms linked with VR to provide a high level of involvement, allowing youngsters to practice numerous social scenarios in a safe and regulated setting. This is especially important for children with ASD, who frequently struggle with social integration and communication. The usage of such immersive environments for therapeutic reasons illustrates AI and VR's potential to provide revolutionary rehabilitation solutions.

Furthermore, the use of immersive VR environments is changing training and rehabilitation methods. This study highlights the efficacy of VR training systems in providing clinical treatments for people with autism, proposing an innovative approach that improves engagement and effectiveness. The immersive quality of VR, paired with AI's adaptive capabilities, enables tailored and context-

relevant training experiences. This integration is essential for developing environments that are both engaging and therapeutically useful, addressing specific needs through tailored interactions.

The theme of enhancing user engagement through immersive environments is also explored in studies related to tourism and educational settings. [23] discuss the impact of VR in the tourism sector, where immersive environments enable potential tourists to explore destinations virtually, enhancing their decision-making process and overall experience. This application of VR, supported by AI, demonstrates how immersive environments can transform traditions.

In the educational context, [15] investigates the effect of immersive environments in improving learning results. By combining AI with VR, educational interventions may be personalized to individual learning needs, providing dynamic and engaging information that boosts knowledge retention and comprehension. This strategy is especially beneficial in early childhood education, when interactive and immersive experiences can greatly improve learning.

[24] demonstrate how AI and VR may generate immersive worlds. Their research uses an AI moderator to protect children from harassment in social VR environments, emphasizing the need of building safe and enjoyable virtual places. This usage of generative AI guarantees that immersive environments stay safe and enjoyable, supporting positive social interactions and protecting vulnerable individuals.

Overall, the research on immersive environments illustrates the revolutionary power of generative AI and VR. These technologies not only improve user engagement and involvement, but they also offer creative solutions in a variety of industries, including therapy, education, tourism, and social interactions. The continuous development and integration of AI and VR are expected to result in increasingly more complex and immersive settings, further transforming how we engage with digital information and one another.

4.2 Content Generation

Content generation within the realm of generative AI and VR represents a transformative approach across various industries, enhancing training, education, and operational efficiencies. [10] highlight the application of AI and virtual simulation technology in electrical engineering, emphasizing its role in improving automation, reducing costs and errors, and optimizing resource allocation. The integration of these technologies into an innovative automation teaching reform model underscores the importance of combining intelligent systems with practical training, ensuring that future engineers are well-equipped with the necessary skills.

[6] present a tangible illustration of how artificial intelligence-driven augmented reality (AR) might transform emergency response training. Their research with firefighter EMTs shows that an AI-enabled AR system, specifically the Juxtopia® Virtual Tutor, can greatly improve training by offering hands-free, interactive clinical training. This method not only simulates real-world operations, but also ensures that EMTs are better prepared for hazardous material incidents. The effective use of AI in content generation for training purposes in high-risk contexts demonstrates the viability of such applications in other industries.

[8] investigate the use of AI and immersive technologies like AR, VR, and MR (collectively XR) in skill training and education. They address the need to modernize learning management systems to include these technologies, shifting away from traditional video formats and toward more interactive and practical skill training environments. By incorporating AI into these systems, they suggest a complete method that increases learning outcomes and prepares individuals for real-world applications.

[3] discuss the increasing use of AI agents, such as chatbots and interactive virtual agents, in higher education. These AI-driven tools facilitate adaptive learning and improve human-machine interactions through natural language processing. By examining the factors influencing the adoption of AI agents in education, the authors highlight the potential of these technologies to personalize learning experiences and ensure educational accreditation. This approach aligns with the broader trend of using AI to generate content that is tailored to individual learning needs, thereby enhancing the educational process.

Content creation through the combination of AI and immersive technologies such as VR and AR has been identified as a watershed moment in a variety of educational and professional fields. [25] underline the importance of digital learning environments (DLEs) in educational institutions, focusing on the interplay of diverse components and their roles in improving educational quality. They identify upcoming technologies such as AI, AR, VR, and IoT as essential enablers of these ecosystems, while also highlighting issues with teacher-supporter interactions, content copyright, and integration into learning management systems.

[26] describe a novel educational platform that integrates physical and virtual domains to enable large-scale network experiments for students. This platform includes an intelligent algorithm center for managing and evaluating students' customized algorithms, which reduces the complexity and cost of data center training. This approach demonstrates how AI may be used to generate practical and scalable content for instructional purposes.

[9] investigates the application of AI-VR interactive models in remote education, namely immersive virtual reality systems. These systems improve the learning process by including multimodal interactions and real-time involvement, as demonstrated by an escape-room-style instructional app. The use of visual, aural, and kinetic cues in this model demonstrates the efficacy of multidimensional learning methodologies in increasing educational outcomes.

[21] examine the transformative power of extended reality (XR) solutions in the healthcare sector. They highlight XR's potential applications in treating disorders including Alzheimer's and PTSD, as well as surgical training and remote consultations. The study emphasizes the early stages of XR-assisted treatments, but also highlights their great potential to revolutionize healthcare delivery by providing immersive, interactive, and practical solutions for patient care and medical training.

Overall, this research demonstrates how AI and immersive technologies are generating unique material in a variety of sectors. In education, AI and VR improve the efficacy and scalability of teaching and learning settings. In healthcare, XR is demonstrating potential for interactive and effective treatment alternatives. The common theme is the use of AI and immersive technology to develop interactive, scalable information tailored to users' unique needs, resulting in major benefits in both educational and professional contexts.

4.3 User Interaction

The concept of user interaction is critical for comprehending the integration of new technology into everyday applications. In the field of digital twin (DT) technology, [27] research examines the creation of exact virtual entities of human bodies. The desire to make human body DT models has grown, particularly with advances in materials science, electrical engineering, and computer engineering. These DT models can detect and analyze complicated bodily signals, bringing them closer to practical applications. The connection between users and these digital copies adds a new level to healthcare, allowing for real-time monitoring and immersive virtual reality experiences that improve overall quality of life. This encounter demonstrates the revolutionary power of DT technology in personal health management and immersive environments.

[1] present a model of hierarchical associative memory for artificial cognitive entities. This concept enables agents to use "life experience" to process situational circumstances and perform efficiently in both virtual and real-world settings. By replicating human cognitive processes, these agents increase user interaction by adapting and navigating depending on previously acquired knowledge and experiences. The multidisciplinary approach, which draws on artificial intelligence, neurophysiology, psychology, and sociology, emphasizes the complexities of developing artificial cognitive agents that can integrate seamlessly into a variety of situations, increasing their utility and efficacy.

[19] study stresses the importance of a comprehensive change in the healthcare industry to safeguard medical professionals from infectious diseases such as COVID-19 and improve patient care. They offer a new visualization technique that uses haptics and is augmented by artificial intelligence algorithms. This approach allows for remote patient assessment and treatment using robotics, giving a precise method of medical picture data visualization while lowering the danger of disease transmission and the workload of medical staff. This technology's engagement improves not just the efficiency and safety of healthcare services, but also the whole patient experience.

[11] concentrate on the agricultural sector, providing a framework for creating a digital twin for an aquaponic system. This system enables real-time monitoring and feedback control by combining IoT technology, databases, and a centralized control system. By allowing users to interact with a virtual model of the aquaponic system, the study shows how digital twins can improve agricultural operations, improve product quality, and promote sustainable practices. The interactive virtual interface offers vital insights and control options, making complex agriculture management more approachable and efficient.

Finally, Ishibashi *et al.,* [7] offer a system for improving engineers' visual inspection skills utilizing virtual reality (VR) technology. This device monitors eye movements to examine the inspection process and provide a thorough understanding of the abilities required. By mimicking real-world circumstances in a virtual environment, the system improves engineer training and skill development while also maintaining the safety and reliability of infrastructure such as bridges. The interaction between the user and the VR system allows for a more in-depth learning experience, encouraging the development of practical skills in a safe, controlled environment.

These studies demonstrate the significance of user contact in the effective deployment of modern technology in a variety of disciplines. Whether through digital twins, cognitive systems, or VR, users' capacity to interact with and profit from these technologies is critical for their general adoption and efficacy.

5. Discussion

The concept of integrating generative AI into virtual reality (VR) exposes profound ramifications and suggests future research areas. Generative AI's impact on VR extends across multiple areas, improving content development, user interactions, and immersive experiences. AI-driven VR applications, which enable realistic simulations and interactive settings, have expanded beyond entertainment to include educational training, healthcare therapies, and industrial simulations. Future study could look into developments in generative AI algorithms designed specifically for VR, with the goal of improving realism, adaptability, and user experience through individualized interactions. Furthermore, as these technologies grow more widespread, inquiries into ethical issues such as data privacy in AI-generated VR content will be critical. As AI advances, multidisciplinary cooperation among AI researchers, VR developers, and domain specialists will be critical to realizing its full potential and tackling emerging difficulties in this dynamic sector.

6. Conclusion

In this article titled "Revolutionizing Virtual Reality with Generative AI: An In-Depth Review," the transformational impact of generative AI on virtual reality (VR) technologies is thoroughly investigated. Generative AI has profoundly altered VR by greatly increasing content generation capabilities, improving user interactions, and enabling more immersive experiences across a wide range of applications. From educational simulations enhanced with AI-driven realism to healthcare advances such as VR-based therapy and medical training, generative AI has advanced VR beyond entertainment and into vital sectors. Furthermore, its incorporation with agricultural digital twinning emphasizes its importance in process optimization and sustainability. Looking ahead, the continual evolution of generative AI promises continued breakthroughs in VR, encouraging innovation and setting new benchmarks for interactive digital worlds.

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