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SYSTEMATIC LITERATURE REVIEW OF MACHINE LEARNING IN VIRTUAL REALITY AND AUGMENTED REALITY

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Abstract

This study aims to conduct a systematic literature review on machine learning methods used in virtual reality (VR) and augmented reality (AR). The method proposed in the SLR consists of three main phases: planning, conducting, and reporting. Researchers used data obtained through Google searches sourced from IEEE Xplore, Springer, Science Direct, Scopus, and Web of Science. The application of inclusion and exclusion criteria is used to select documents. The findings from this study consist of countries involved in machine learning research in the VR and AR fields, machine learning methods, technology used, and work sectors that use machine learning in the VR and AR fields. The results also show that when the machine learning method is used in VR and AR applications, the main advantages are high efficiency and algorithm precision. Moreover, this research observes that machine learning is the most widely applied artificial intelligence scientific technique in VR and AR applications. The results of this systematic literature review show that the combination of machine learning and VR and AR methods contributes to trends, opportunities, and applications in the fields of engineering, arts, education, industry, medicine, tourism, and technology.

Keywords : machine learning, virtual reality, augmented reality

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INTRODUCTION

Virtual Reality (VR) and Augmented Reality (AR) are two technologies that have developed rapidly in recent years in the fields of computer graphics and human-computer interaction[1]. Both provide different experiences when using technology to convey information or create interactions with the digital world. VR refers to technologies that allow users to experience and interact with fully-created digital environments, often isolating them from the real world. VR provides the ability to train individuals to deal with complex and dangerous situations by immersing them in a virtual environment and enabling them to learn about the process of acquiring knowledge and skills. In a VR experience, the user wears a special headset that provides visual, audio, and sometimes tactile or body movement sensations. The main goal of VR is to provide a highly immersive experience that makes you feel like you are actually in a digital environment [2].

Meanwhile, AR is a technology that combines digital elements with the real world [3]. In an AR experience, users can see the real world around them through the camera on a smartphone or tablet or through special AR glasses. Digital elements, such as 3D objects, additional information, or animations, are added to the real environment via the device screen. The main goal of AR is to enhance real-world experiences with relevant digital information [3].

Both of these technologies have a long history and have developed a lot in recent years. VR was first developed in the 1960s, while AR emerged in the 1990s [4]. However, recently, VR and AR have experienced a significant increase in popularity and usage, especially in gaming, education, medicine, engineering, business, and other fields [5]. The increasing application of artificial intelligence techniques to evaluate performance in VR and AR simulators has led to an increase in the volume and complexity of publications bridging the fields of computer science, medicine, education, and others.

Machine learning (ML) is a field of artificial intelligence that studies how computers are able to learn from data and make decisions or predictions automatically without having to be explicitly programmed [6]. VR and AR are technologies capable of creating interactive digital experiences using realistic visual and audio media. VR creates virtual worlds that are completely separate from the real world, while

AR creates digital experiences that complement or add to the real world.

The combination of machine learning, VR, and AR provides enormous potential for creating interactive experiences that are more personal and immersive [1]. In this case, machine learning can be used to enhance VR and AR experiences by producing more realistic content and optimizing interactions with users. The use of machine learning in VR can produce content that is more dynamic and responsive to user actions, so that users can have a more interactive and engaged VR experience. On the other hand, AR can be used to increase user engagement in real environments by adding digital elements such as data visualizations or interactive guides.

In addition, machine learning can also be used to develop sophisticated image processing algorithms that can be used in facial recognition and the recognition of user body movements in VR and AR environments [7]. This will help improve the user experience and provide a more immersive experience. The use of machine learning in VR and AR provides great potential for improving the quality and interactivity of digital experiences that can bring enormous benefits to various fields such as engineering, arts, education, industry, medical, tourism, and technology.

This article applies the Systematic Literature Review (SLR) method, in which the process collects articles with predetermined keywords. Article searches were carried out using the publish with Perish 8 Tools application on the IEEE Xplore, Springer, Science Direct, Scopus, and Web of Science databases. The articles obtained are then subjected to a review process to be able to provide answers to the questions contained in the method stages in this article. The purpose of this research is to find out the trend of machine learning in the field of VR and AR, the machine learning methods used, the technology used, and the sectors that use machine learning in the field of VR and AR. This research establishes specific inclusion and exclusion criteria to distinguish papers that describe the use of machine learning in VR and AR.

METHOD

This research method uses the Systematic Literature Review (SLR) guidelines proposed by Kitchenham and Charters in Software Engineering research [8]. According to these guidelines, SLR consists of three main phases: planning, conducting, and reporting. The SLR stages used in this study are described in Figure 1.

The search process is carried out using the Publish or Perish 8 application. Publish or Perish 8 is a software program that can retrieve and analyze academic situations from various sources to obtain raw data and then analyze it into useful information [9]. In this study, researchers used data obtained through Google searches sourced from IEEE Xplore, Springer, Science Direct, Scopus, and Web of Science..

Searches were performed from December 2022 to February 2023, search strings were executed in title, abstract and keyword metadata for each database. Based on a search using the Publish or Perish 8 application, you get 43 articles related to the keywords machine learning, VR and AR. Research questions are made according to the needs of the chosen research topic. This study focuses on its use in education and answers the following questions:

1. When is the trend in machine learning research in the field of VR and AR?
2. Which countries are involved in machine learning research in the VR and AR fields?
3. What types of machine learning methods are used in the VR and AR fields?
4. What technologies are used to generate immersives for machine learning?
5. In what sectors do you use machine learning in the VR and AR fields?

The next step after planning the review is developing a review protocol aimed at determining the method to be used in performing SLR. This protocol stage is necessary in order to reduce researcher bias. This stage consists of research questions, strategies for finding the main studies, criteria for selecting articles, procedures for selecting articles, and procedures for assessing the quality of articles.

At the Conducting Review stage, searching for articles to answer predetermined research questions, the process of searching for relevant papers with the Publish or Perish 8 tools uses several keywords: "machine learning" and "virtual reality" with the Boolean operators "AND" and "machine learning" and "augmented reality" with the Boolean operator "OR". A search string construction search that automatically returns articles in the Scopus, IEEE Xplore, Springer, Science Direct, Scopus, and Web of Science databases. To support the definition of search strings, a set of terms is defined following the PIO paradigm [8]:

1. *Population*: machine learning
2. *Intervention*: virtual reality, augmented reality,
3. *Outcome*: country, method, technology, sector

The “OR” boolean operator is used to combine related terms and the “AND” operator to combine population, intervention, and outcome terms. This study applied several inclusion and exclusion criteria to select the articles to be used. These criteria are described in Table 1. The initial process of this research was to select articles based on titles related to the research topic; for each title, there was a provision that there should be no duplication. The following criteria analyze the abstract of each selected article to get an idea of whether the article is suitable, not suitable, or not suitable at all based on the inclusion and exclusion criteria that have been made. Articles that are inappropriate or inappropriate will be eliminated, while articles that are suitable will be further analyzed regarding their contents. For each article, the one-level backward snowballing technique is carried out with a total of 3 articles to identify other research that is potentially relevant to this research through bibliographical reference [10]. Based on the final results, 26 relevant articles were selected from the 43 selected articles. Furthermore, a quality assessment was carried out to find out in more detail the inclusion and exclusion criteria, as shown in Table 1, that were applied in the search [8]. After carrying out several stages of analysis to get articles that match the criteria, the result is a total of 20 articles. Articles are classified by year of publication in the range from 2018 to 2023, as shown in Figure 2.

The reporting stage (reporting the review) consists of data extraction and discussion activities, report presentation (writing and formatting), and report evaluation. The results of the discussion and presentation of research results will be discussed in Section 3, and future research work will be discussed in Section 4.

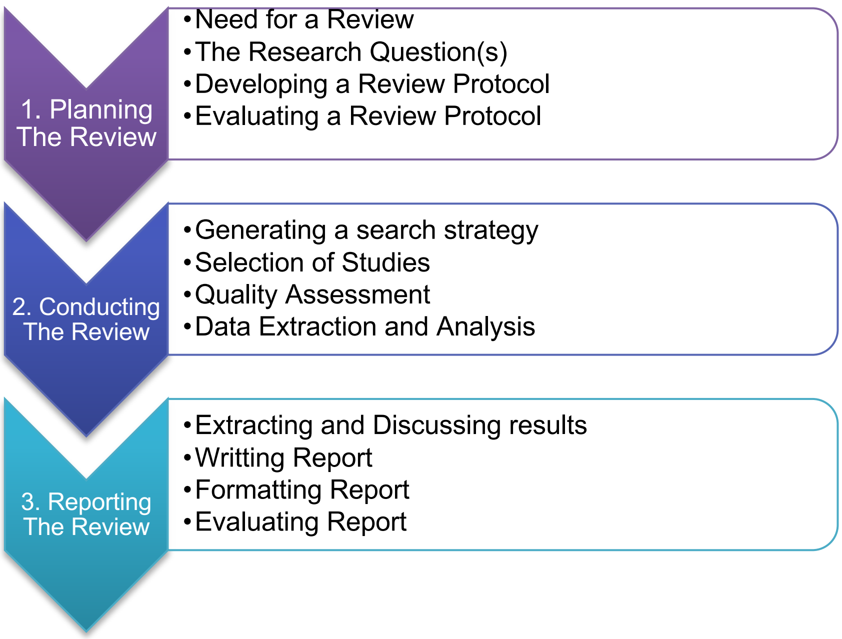

Figure 1. SLR phases by Kitchenham and Charters

Table 1. Inclusion and Exclusion Criteria

Kriteria	**Deskripsi**
Inclusion	The article used discusses the use of machine learning in virtual reality and augmented reality; articles published within the 2018-2023 timeframe;
Exclusion	Articles that do not discuss machine learning in virtual reality and augmented reality; Literature review articles are not included; Articles that do not report the methods used Duplicate article

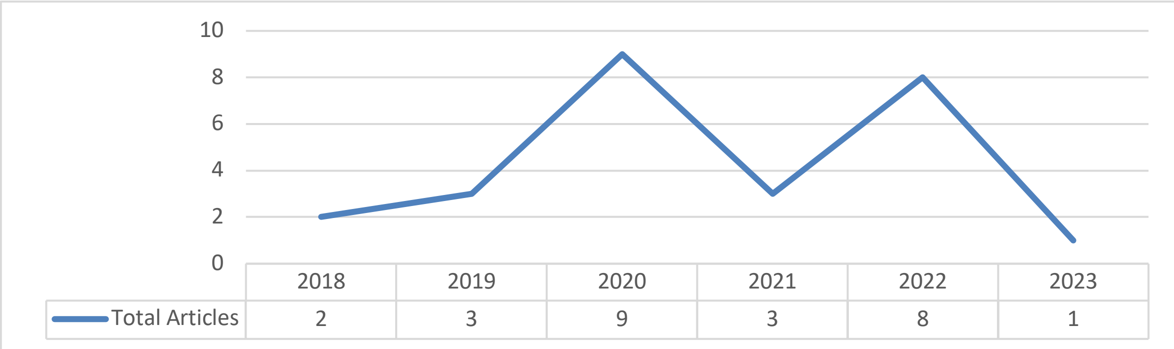

Figure 2. Number of Articles by Year of Publication

RESULT AND DISCUSSION

A. Result

Many countries around the world are currently conducting research and development in the fields of machine learning, augmented reality (AR), and virtual reality (VR). As a global technology hub, the United States is one of the leading countries in machine learning, AR and VR research and development. Many large companies, such as Google, Microsoft, and Facebook, have research centers in the United States. China is another country that is known to be active in conducting research and development in the fields of machine learning, AR and VR. Many large companies, such as Tencent, Alibaba, and Baidu, also have research centers in China. Canada has a thriving technology industry and is a research center for machine learning, AR, and VR. Universities such as the University of Toronto, the University of British Columbia, and McGill University also have strong research centers in this area. The UK has several leading universities, such as the University of Oxford and the University of Cambridge, which are known to be active in research and development of machine learning, AR and VR. In addition, companies such as Google and Microsoft also have research centers in the UK. Germany also has a thriving technology industry and several leading universities, such as the Technical University of Munich and the University of Stuttgart, which are known to be active in research and development of machine learning, AR, and VR. Companies such as Bosch and SAP also have research centers in Germany. Meanwhile, in Indonesia, more companies in the field of technology and startup companies are building VR and AR for games, education, and training.

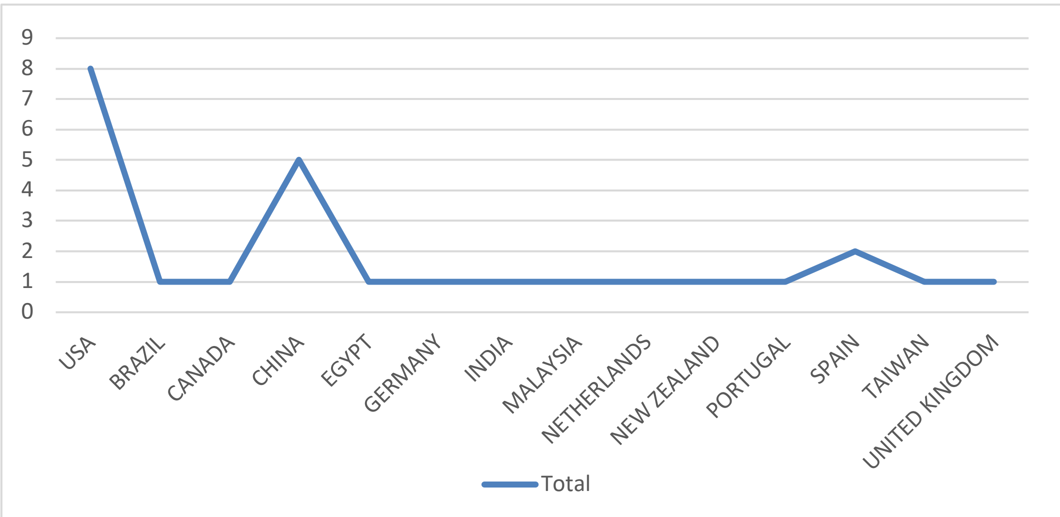

Figure 3. Countries contributing to machine learning research using VR and AR

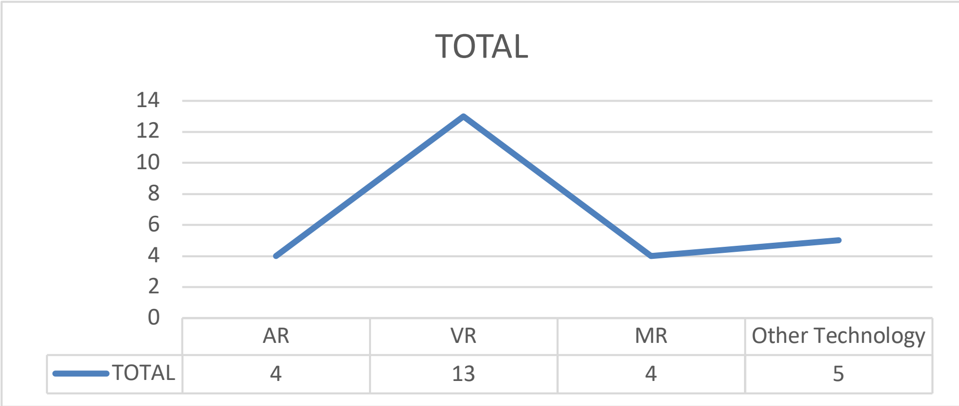

Figure 4. Technology used

The results of this literature review research process are countries involved in machine learning research on VR and AR, namely the United States of America with 8 articles [1], [11], [12],[13],[14],[15],[16],[17]. China found five articles that examined the use of machine learning in VR and AR; Spain had two studies; the rest were from Brazil, Canada, Egypt, Germany, Malaysia, New Zealand, Portugal, Taiwan, and England, each with one study. Countries that contribute to machine learning research in virtual environments are described in Figure 3.

The VR tools used to implement machine learning methods consist of Oculus Quest, VR Mobile, Google Cardboard, smartphones, HTC VIVE with pupil lab enhancements, Cave Assisted Virtual Environment (CAVE), and Playstation VR Device. While the AR tools used are more focused on smartphone use. As previously discussed, AR is a technology that allows users to see the real world with added digital elements, while machine learning is a technology that allows machines to learn from data and improve their performance over time. Figure 4 shows the technology used in machine learning research.

However, there are tools that can be used to integrate AR and ML, such as ARKit (for iOS) and ARCore (for Android). Both of these platforms provide AR frameworks that can be used to build AR applications using machine learning techniques. Vuforia is a tool that provides an AR development platform that can be used to integrate machine learning techniques. Unity is a game engine application that can be used to build AR applications using machine learning techniques. Tensorflow.js is a JavaScript library application that can be used to build AR applications with machine learning techniques. AR.js is a JavaScript library application that can be used to build AR applications on the web with machine learning techniques. Using these tools, developers can build AR applications that can learn from data and improve their performance over time, such as in object recognition, face detection, or handwriting recognition.

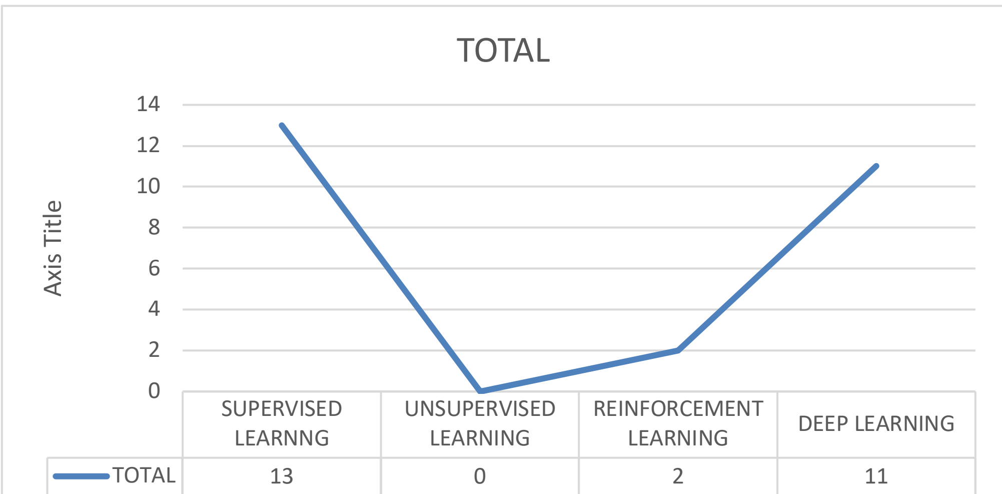

Figure 5. Machine learning method implemented

The types of machine learning methods used in the field of virtual environments are supervised learning, reinforcement learning, and deep learning. The application of the unsupervised learning method was not found in an article search. In Figure 5. is a machine learning method, which is a finding from the results of the literature review.

Supervised learning is a machine learning technique in which a machine learning model is given known input and output data [1]. The goal is to produce a model that can predict the right output from a given input. Supervised learning can be used to study user behavior and preferences when interacting with virtual environments and then build models that can provide more personalized and effective VR and AR experiences.

Supervised learning models can be trained to recognize the user's body movements and positions in a virtual environment [18]. It can be used to control a user's avatar in VR and AR environments or to improve overall VR and AR interactions and experiences. Supervised learning models can be trained to learn user behavior when interacting with virtual environments, such as navigation preferences or interactions with objects. This can help VR developers build more personalized and effective environments.

Supervised learning models can also be used to learn user preferences for graphic settings and visual displays [19]. This can help VR and AR developers build more realistic and engaging environments. Supervised learning models can be trained to learn user preferences for viewing and a comfortable VR environment. This can help VR developers build environments that better suit user preferences and prevent distractions such as nausea and dizziness. In addition, it should also be noted that supervised learning is not always suitable for all types of problems, so it needs to be considered carefully before implementing this method in a VR environment.

Reinforcement Learning (RL) is a machine learning method that involves agents learning to choose the best course of action in different situations to achieve certain goals [20]. The application of reinforcement learning in virtual reality (VR) and augmented reality (AR) can assist in developing a more realistic and interactive VR environment. Reinforcement learning can be used to develop intelligent characters who can interact with the VR environment. These characters can learn from their experiences and continuously improve their skills through interaction with the environment. Reinforcement learning can be used to train users in a VR environment. By using reinforcement learning, users can learn from their experiences and improve their skills at interacting with VR environments. Reinforcement learning can also be used to improve user performance in both VR and AR environments. Agents can learn from user experiences and provide useful feedback to help users improve their performance. RL can be used to develop more realistic and interactive VR environments. Agents can learn from their experience in the environment and provide useful feedback to improve the quality of the VR environment..

Deep learning can be used in virtual reality (VR) applications to enhance the user experience [21]. The deep learning object recognition method can be used to recognize objects in the virtual world more accurately and quickly [22]. An example is the use of the convolutional neural network (CNN) technique to detect and recognize objects in the VR world. The deep learning gesture recognition method can be used to recognize user movements and actions in the virtual world [18]. This can increase the interaction between the user and the virtual world, for example, in VR games. The deep learning speech recognition method can be used to recognize the user's voice in the virtual world [15]. This can improve VR's ability to respond to user voice commands, for example in VR applications designed to assist people with disabilities. The deep learning method of natural language processing can be used to understand natural language and produce more natural responses in virtual worlds [23]. This can improve the quality of interaction between users and virtual worlds, for example, in VR applications designed for interaction with AI characters. The deep learning predictive analytics method can be used to predict user behavior in the virtual world, so that the virtual world can respond more precisely and effectively [19], [24]. An example is the use of reinforcement learning techniques to optimize the user experience in VR games.

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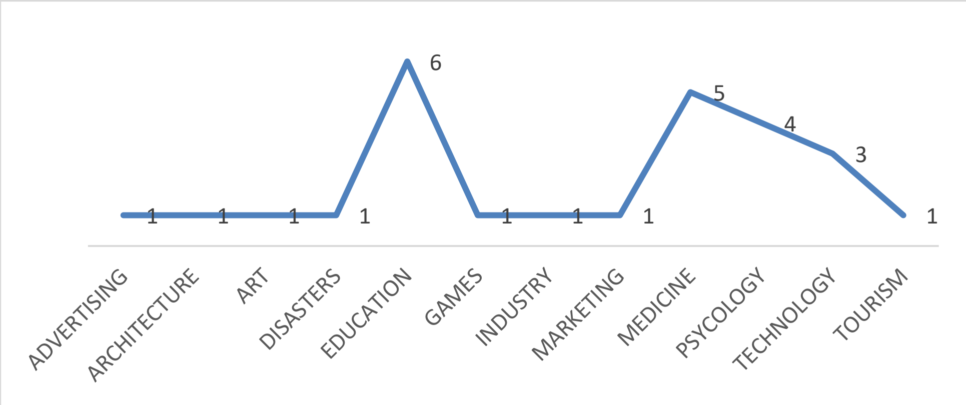

Figure 6. Machine learning application areas

Figure 6 presents the fields that apply machine learning methods to VR and AR, namely in the field of psychology, as many as 4 studies; in the field of education, as many as 6 studies; in the field of health, as many as 5 studies; in the field of technology, 3 studies; and 1 study each in the fields of advertising, architecture, art, disaster, games, industry, marketing, and tourism. The application of machine learning in VR and AR can help teaching and learning by creating interactive simulations that can increase students' understanding of subject matter. The application of machine learning in VR and AR can help doctors and medical students practice certain medical techniques, such as surgery or other medical procedures, before facing real-life situations. The application of machine learning in VR and AR can help engineers or technicians carry out more realistic and accurate simulations in hazardous environments, such as power plants or chemical refineries. The application of machine learning in VR and AR games can create smarter and more realistic characters or objects in the game environment, so that the gaming experience becomes more interesting and enjoyable. Overall, the application of machine learning in VR and AR can provide many benefits in various ways. field. This proves that this technology has great potential to be used as an effective tool for improving the quality of human life.

B. Discussion

Machine learning (ML) can be applied in the fields of virtual reality (VR) and augmented reality (AR) for various purposes, such as pattern recognition, motion recognition, and image processing. Machine learning can be used to recognize user movements in virtual and augmented environments [1]. According to Lamb, using the Random Forest Model shows a good fit of the model in terms of identifying the right answers and wrong answers [1]. Machine learning can also be used to predict hand and finger movements on VR or AR devices equipped with motion sensors, such as the Oculus Touch or HTC Vive [25],[26]. Machine learning can be used to process images generated from cameras on VR or AR devices to recognize certain objects or shapes [21],[23]. Machine learning can be used to recognize objects in virtual or augmented environments, such as recognizing cars or trees in the resulting 3D objects. Machine learning can be used to provide guided learning experiences to users in VR and AR [7]. Machine learning can be used to deliver virtual classes or training using specially designed avatars or environments. Machine learning can be used to predict user behavior in virtual and augmented environments [24]. Machine learning can be used to predict whether a user will select a particular object in a virtual or augmented environment based on previous data about the user's preferences.

The results of the literature review analysis on 26 articles contained machine learning algorithm methods that were compared to find the best method used in solving problems in VR and AR. Machine learning algorithms generally rely on much larger sample sizes as discrimination becomes more complex. Brouwer's research results demonstrate the clinical potential of the combined techniques of VR simulation, eye tracking, and machine learning [25].

The Support Vector Machine (SVM) method can be applied to Virtual Reality (VR) applications for various purposes, such as pattern recognition, motion recognition, and image processing. One example of using SVM in VR is in motion recognition. SVM can be used to recognize the user's body movements, such as raising hands or bending knees. This can help control avatars or objects in the virtual world. SVM can also be used in image processing to recognize objects in virtual environments, such as cars or trees, and allow users to interact with these objects.

The results of research using the SVM method, namely Zhihan et al., show that the CSWC-SVM algorithm has the advantage of short time consumption[11]. The algorithm designed in this study can improve detection accuracy and is feasible to operate in a virtual reality environment, which can provide theoretical references and data for other related studies [11]. Mariano Alcañiz Raya et al., research aims to build a virtual environment to teach various skills to children who have autism spectrum disorder (ASD), both from the cognitive, interactive, and emotional aspects [7]. This study uses C-SVM, which is optimized using the sigmoid kernel function.

Using the SVM algorithm to train the classifier when classifying data and comparing different training sample sizes and different kernel functions for empirical analysis and in-depth analysis of the accuracy of both and the impact of using the model [27]. According to Liang Wu et al., based on a comparative analysis of SVM-KNN data, more real and effective results were obtained [27]. Raya et al., research aims to investigate whether the machine learning method using the SVM method on features and movement frequency can be useful in differentiating children with autism spectrum disorder (ASD) from children with normal neurodevelopment [6].

Zhang et al. conducted research to address the problem of human motion recognition in multimedia interaction scenarios in a virtual reality environment, using a classification and motion recognition algorithm based on the linear discriminant analysis (LDA) algorithm and support vector machines (SVM) [18]. he study of Zheng et al., presented the first systematic investigation of the use of pupillometry as a single feature to classify emotions into four distinct classes using stimuli in a virtual reality environment [28]. The advantage of the SVM method for classifying emotions using student data is that it gets better results compared to the other two classifiers, namely K-nearest neighbor (KNN) and Random Forest (RF), conducted by Zheng [28].

The experimental results of Xinchu Huang et al., related to classification, show that the rough set (RS) and SVM classifier models based on parameter optimization proposed in their research reduce false fire detection alarms and use fire feature selection using VR as well as fire recognition detection in handling fires and have very stable stability good at increasing the accuracy of fire forecasting [22]. he SVM method as a classifier was used by Sriporn et al., to create an effective model for predicting tourist behavior at the national virtual museum [24]. However, keep in mind that implementing SVM in VR and AR can be resource intensive, especially when applied to complex data and on a large scale. Therefore, it is necessary to evaluate and optimize before implementing SVM in VR and AR to ensure optimal and efficient performance.

In addition to the use of the SVM method, many other studies use deep learning methods. Huy Le et al., presented a new method to incorporate machine learning to detect and track marker targets in augmented reality applications using deep neural networks [21], [26]. The deep neural network module uses YOLOv3 as the main object detection model and ARKit as the main software for developing application prototypes. In addition, Huy Le's research approach can be helpful in education, where the content of textbook images must remain unchanged, and high detection accuracy is required [21]. Research by Xu et al., analyzed and processed visual interaction screen data based on calculations for predicting image differences built with deep learning and establishing an image prediction model [29].

On the use of machine learning in the fields of industry and marketing, there have been several studies conducted. Upadhyay et al., research aims to overcome the long product buying process in the retail industry and help customers who experience language barriers while selling products to customers with different language backgrounds [23]. This study combines machine learning algorithms with the R-CNN algorithm, using augmented reality to identify products [23]. Zheng et al, designed a study for an immersive marketing environment using the Graph Neural Network (GNN) model to enhance the user's shopping experience and promote sales [30]. Dobre et al., research introduces elements of data processing related to immersive machine learning with the Long-Short Term Memory (LSTM)-Recurrent Neural Network method to detect social engagement and shows how creatives can use virtual reality to expand their capabilities to design more engaging experiences [31].

On the use of machine learning in the fields of psychology and games, there have been several studies conducted. The LSTM-based model was used by Hofmann for affective decoding, i.e., to predict subjective emotional arousal from the alpha frequency component of the EEG [32]. Research Gomes et al., have developed an emotional agent based on the reinforcement learning method [20]. This research develops automatic virtual characters that are designed with different emotional profiles for video games as well as virtual characters that mimic human emotions [20]. Ishaque et al., research used virtual reality (VR) video games to reduce stress. Physiological signals captured from the electrocardiogram (EKG), galvanic skin response (GSR), and respiration (RESP) are used to determine whether the subject is stressed or relaxed [33].

The advantages of using machine learning methods in VR and AR are widely implemented in various fields. Machine learning can be used to improve the quality of visualization in VR and AR, such as by increasing image sharpness, removing noise and artifacts, and increasing object detail and resolution. Machine learning can be used to enhance user interaction with virtual or physical environments in VR and AR. Machine learning can be used to improve security in VR and AR environments. The use of machine learning can help prevent accidents or hazards in the physical environment associated with using AR. Using machine learning in VR and AR can help improve the quality of visualization, user interaction, and security.

CONCLUSION

Machine learning can be used to enhance VR and AR experiences by enabling systems to learn from and adapt to data collected from virtual or physical environments. However, effective implementation of machine learning in VR and AR requires a solid knowledge of the technology and application requirements, as well as the ability to leverage data appropriately and effectively.

The use of machine learning algorithms in the future needs to be further developed, especially in VR and AR designs. For example, real-world game development could take place in VR without any difference from the real world or the use of haptic technology. In the future, machine learning can also help AR track movements, such as head or hand movements. Thus, AR can adjust the digital display based on the user's movements, so that the AR experience can be more realistic and interactive. Research using machine learning methods to help improve image quality in AR, such as removing noise, improving contrast, or adjusting colors, needs to be done in the future. Machine learning can also help AR analyze real environments, and if the user is in an environment with poor lighting, AR can adjust the brightness or color of the digital display to keep things clear. However, implementing machine learning in virtual reality requires known input and output data, which requires careful data collection and effective training methods.

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