

Research on the Integrated Application of Artificial Intelligence and Virtual Reality in Smart Home Systems

Gaoyang Li^{1,*},

Tong Ye²,

Jiayi Zhong³

¹Faculty of Innovation Engineering,
Macau University of Science and
Technology, Macau, China

²Faculty of Art and Design,
Heilongjiang Oriental University,
Harbin, China

³Faculty of Digital Media
Engineering and Humanities, Hunan
University of Technology and
Business, Changsha, China

*Corresponding author:

1210019282@student.must.edu.mo

Abstract:

With the advancement of artificial intelligence (AI) and virtual reality (VR) technologies, smart home systems are gradually transforming people's lifestyles. This paper explores the applications of AI and VR in the smart home domain, focusing on how these technologies enhance the intelligence and personalization of home life. First, the paper describes the fundamental concepts of AI and VR technologies and their current applications in smart homes, including devices such as smart thermostats, smart lighting, and smart security systems. Subsequently, the paper provides detailed case studies of AI and VR applications in smart home design, home entertainment, and remote monitoring, emphasizing the immersive experiences and interactive advantages these technologies offer. Additionally, the article discusses the challenges posed by the integration of these technologies, such as privacy protection and data security concerns. Finally, the paper concludes with an overview of the development prospects of AI and VR technologies in the smart home sector, highlighting their potential to enhance residential safety, convenience, and comfort.

Keywords: Artificial intelligence; virtual reality; smart home; user experience; data security

1. Introduction

As technology continues to advance, artificial intelligence (AI) and virtual reality (VR) are gradually permeating various aspects of daily life, particularly in the smart home sector, where they are leading a revolution in living environments [1]. AI technology empowers home devices to become intelligent, enabling them to learn user habits and automatically adjust

to meet personalized needs, while VR technology creates immersive virtual environments that provide users with a novel interactive experience. This transformation significantly enhances the convenience and comfort of home life and opens up vast prospects for the future development of smart homes. The application of AI and VR technologies can markedly improve home safety, energy management, and overall living experiences, which is crucial for addressing

the growing energy demands and enhancing living quality. Currently, research and application of AI and VR technologies in the smart home field are rapidly evolving. Smart devices such as smart thermostats, smart lighting, and smart security systems have begun to gain popularity and widespread acceptance. However, despite the numerous conveniences these technologies offer, their applications extend beyond home automation to include home entertainment, remote monitoring, and interior design. For instance, users can preview design effects using VR technology before renovations or control smart devices remotely through AI technology [2].

Although the application prospects of AI and VR technologies in smart homes are broad, research on how these technologies specifically impact users' daily lives remains insufficiently explored. This paper aims to analyze the current state of AI and VR technology applications in smart homes, focusing on how these technologies enhance the intelligence of home life. It will examine their performance in various application scenarios and discuss their potential and challenges in improving user experience and ensuring data security.

2. The Concept of AI and VR

AI is a concept that refers to the intelligence exhibited by machines created by humans, often referred to as machine intelligence. With the rapid advancement of technology, AI is continually transforming various aspects of our lives, particularly in the realm of smart home systems. AI has the capability to simulate human cognitive functions, such as learning and problem-solving, and is expected to replace many traditional human jobs in the future. AI can be defined as a machine or computer system that simulates cognitive functions associated with the human mind.

One of the core characteristics of AI is its ability to reason, learn, and act. AI can perform logical reasoning and handle complex situations through self-learning and autonomous decision-making, capabilities that typically require human intelligence. Today, many smart home devices are embedded with such AI technology, allowing them to automatically adjust their operational states based on user habits and preferences. For example, a smart thermostat can learn the living patterns of its inhabitants and automatically adjust the indoor temperature according to their preferences, thereby enhancing comfort and saving energy [3]. Another important feature of AI is its interdisciplinary nature. AI combines knowledge from multiple fields, including computer science, data analysis, and neuroscience. Smart home systems typically rely on deep learning algorithms to collect and analyze environmental data, thereby optimizing device performance. With

the support of such technology, smart home systems can respond in real-time under various conditions, providing users with a safer and more convenient living experience. The development of modern AI primarily hinges on machine learning, particularly deep learning methods. By analyzing vast amounts of data, AI systems can demonstrate exceptional capabilities in areas such as image recognition and natural language processing. This is widely applied in smart homes; for instance, smart speakers utilize natural language processing technology not only to execute voice commands but also to recognize the emotional tone of the speaker, adjusting tone and pace to enhance interaction quality [4]. Moreover, with advancements in internet technology and big data, AI is transitioning from individual intelligence to collective intelligence. This shift enables smart homes to connect various devices through the network, facilitating seamless collaboration among different brands and functionalities. For example, when a user arrives home, the smart lock can automatically unlock, the lighting can adjust according to their preferences, and background music can play simultaneously—this intelligent collaboration enhances the convenience of daily life.

In this context, VR has gradually merged with smart home technology as a method of creating three-dimensional virtual worlds through computer generation. VR provides users with an immersive experience; its interactivity and sense of presence make one feel as though they are situated within a completely new and realistic environment. In applications for smart homes, users can remotely monitor their home situations using VR technology and simulate device responses under various scenarios. For example, users can utilize VR for home design previews, making real-time adjustments to furniture arrangements and interior layouts to facilitate better planning prior to renovation.

The sense of immersion is one of the most significant features of virtual reality. Compared to traditional methods of home control, the interactive experience of VR is more intuitive and natural. Users can engage with multidimensional information in the virtual environment through various sensors, and even control smart appliances using VR devices, making the operation more engaging and participatory. Moreover, VR technology can not only recreate real-world scenes but also generate scenarios that are difficult to imagine, offering unparalleled experiences for users. For instance, through VR technology, users can simulate different climate conditions within their smart home environments to better assess the effectiveness of their heating, ventilation, and air conditioning systems.

However, the integration of AI and VR also presents new challenges. In terms of privacy and data security, smart home devices collect vast amounts of user behavioral data, and if such data is misused, it could lead to privacy

breaches. Furthermore, the application of VR technology in smart homes must also take user physical and psychological well-being into account; ensuring users feel safe and comfortable within virtual environments poses a critical challenge that developers must address.

3. The Application of AI and VR in Smart Home

3.1 VR Technology in Smart Home

AI and VR are gradually showcasing immense application potential in home settings. AI technology can intelligently adjust the operation of home devices by learning users'

habits and preferences. For instance, a smart lighting system can automatically adjust brightness and scenes based on daily activities, while a smart speaker can play music or control multiple devices based on voice commands [5]. On the other hand, VR technology provides users with a more immersive experience, allowing them to simulate home layouts, engage in interior design, or view the working status of home devices in real-time, enabling more intuitive choices and adjustments. This integration not only enhances the comfort and convenience of living environments but also lays the groundwork for the widespread adoption of smart homes in the future, making family life increasingly intelligent and personalized. Table 1 shows the comparison of smart home and ordinary furniture.

Table 1 The comparison of smart home and ordinary furniture

Smart Home/ General Furniture		peculiarity		merit		shortcoming	
Smart refrigerators	Traditional refrigerators	The refrigerator can be controlled in temperature, and the refrigerator mode can be changed automatically.	Simple shelf life tool.	Keep your food in the best storage condition at all times, and know the quantity, freshness, and quality of food in your fridge anytime, anywhere.	It is durable and easy to repair and replace.	The cost is high and the technology is dependent.	The function is single and the degree of intelligence is low.
Smart washing machine	Traditional washing machine	It can automatically set different washing processes according to the material, weight and size of the clothes.	Fool-style laundry, with a single function, cannot automatically identify the function.	There are different processes according to the material of different clothes, and the color and material of the clothes will not be damaged.	Easy to operate and affordable.	The cost is high and the technology is dependent.	The function is single and the degree of intelligence is low.

Smart lighting	Conventional lighting	Achieve timing adjustment function, brightness change adjustment, scene adjustment, and composite control through remote control switch;	The light is single, non-transformable, non-adjustable, single switch control, and cannot be controlled remotely.	It's quick and easy.	Good stability and simple to use.	The cost is high and the technology is dependent.	It's not convenient enough. Single function.
Smart security	Traditional security	By introducing machine learning methods into smart home security systems, the security of the system can be greatly improved.	Door locks, iron railings on windows.	The pre-set model corresponds to different scenarios, responds quickly, and reduces or avoids losses.	Affordable and easy to operate.	High cost, technology dependency, privacy and data breach risk.	Hackers hack into the surveillance system and are unable to react quickly.
Intelligent robot vacuum	Traditional manual cleaning	Just charge it, set the line, and when you leave the house, you can sweep the floor with one click, and the bottom of the bed and cabinet can also be easily cleaned.	Manual labor	It's quick and easy, and hidden corners can be cleaned too.	It is easy to operate and low cost.	The cost is higher.	It's very hard, it takes up rest time, and some corners such as the bottom of the bed can't be scanned.

3.1.1 View 3D panoramic view/smart home configuration and installation

VR captures three-dimensional data of houses through 3D scanning devices or stereo cameras. After advanced computer processing and optimization, this data is transformed into highly interactive virtual scenes. When users wear VR headsets or other related VR devices, they can immerse themselves in the spatial layout and decoration style of the house, achieving a near-realistic immersive experience. Additionally, users can interact with the virtual environment in various ways, such as opening doors and windows, adjusting lighting, and more, to intuitively evaluate the actual use of the space. This high level of interactivity not only significantly enhances user engagement but also greatly improves the efficiency of property viewing [6].

For example, the “Linggan VR Home Viewing” software, launched by well-known platforms such as 58.com and

Anjuke, integrates multiple cutting-edge technologies. In terms of information accuracy and visual experience, “Linggan VR Home Viewing” is at the forefront of the industry, providing a novel way for homebuyers around the world to view properties that breaks through traditional time and space limitations. Using VR devices or mobile applications, users can browse properties of interest anytime and anywhere, enjoying an experience that closely mimics an on-site visit. This solution not only enriches the options for property viewing but also greatly facilitates the remote home-buying process, significantly enhancing the service quality and customer satisfaction in the real estate industry.

3.1.2 Smart home design and decoration

The origin of smart homes can be traced back to the late 20th century, when home automation was the main research direction. However, due to technological limitations at the time, the field of smart homes did not develop

rapidly. With the continuous advancement of intelligent technology and the gradual reduction of prices, the development of smart homes has entered a period of rapid growth, becoming a hot topic in the field of technology today.

Users can enter virtual spaces through VR devices such as head mounted displays (HMDs) to view and experience smart home design solutions in real-time. This technology enables users to immerse themselves in the future living environment, thereby better understanding design solutions and making decisions. In the virtual environment, users can freely move furniture, adjust lighting, change color combinations, etc., and view the adjusted effects in real time. This interactive design experience greatly enhances user engagement and satisfaction. VR technology can provide accurate spatial perception, helping designers and users to conduct precise spatial measurements and layout planning in virtual environments. Users can simulate the real placement process in virtual space through gestures or controllers, optimizing space utilization and layout design. VR technology can simulate the effects of different materials, such as wood, stone, metal, etc. Users can observe the texture performance of these materials under different lighting conditions in virtual space. Users can try different color matching schemes in a virtual environment, view the effects in real-time, and find the color combination that best suits their preferences.

3.1.3 Virtual home entertainment and leisure

By wearing VR helmets or glasses, viewers can immerse themselves in the scenes and plot of the movie, experiencing adventures and stories together with the movie characters. This immersive viewing experience is more immersive and fun than traditional cinemas. Through VR, family members can visit scenic spots and museums around the world from the comfort of their own homes. This virtual travel method not only saves time and money, but also brings unique adventure experiences [7]. VR technology can also be used to teach life skills such as cooking and repairing household appliances. Family members can engage in practical exercises in a virtual environment, increasing the fun and practicality of learning. Through VR technology, family members can invite distant relatives and friends to participate in virtual games or other entertainment experiences together. This new way of communication is not limited by time and space, bringing people closer together.

The most significant difference between virtual home entertainment and leisure methods and traditional leisure methods lies in their immersive, interactive, and personalized experiences. Traditional leisure activities such as reading, outdoor activities, and watching movies, while

providing relaxation and entertainment, often lack deep interaction with the environment and personalized customization. Virtual home entertainment and leisure, on the other hand, have built a fully user led and customized digital world through advanced technologies such as VR and augmented reality.

3.2 AI Technology in Smart Home

3.2.1 Smart home control

Smart speakers such as Amazon Echo, Google Home, Xiaomi Xiaoi, etc. have become the voice control center in smart homes. Users only need to issue voice commands to control the lighting, television, air conditioning and other devices in their homes, achieving intelligent control of the entire house. Through gesture recognition technology, users can make specific gestures in the air to control smart home devices, such as turning on and off lights, adjusting brightness, etc. Smart refrigerators, smart washing machines, smart air conditioners and other household appliances can be connected to smart home systems to support remote control and scheduled appointments. Users can check the status of home appliances and adjust their working modes anytime and anywhere through mobile apps or voice assistants [8]. The intelligent lighting system can automatically adjust parameters such as light brightness and color temperature based on factors such as ambient lighting and personnel activities, creating a comfortable living atmosphere. Users can also set different lighting scene modes through mobile apps or voice assistants to meet different living needs.

3.2.2 AI technology in home security systems

By integrating high-definition cameras and advanced image recognition algorithms, the security system can recognize the faces of family members and visitors in real time. This technology can not only improve home security, but also effectively prevent forgery attacks, such as using photos or videos to deceive door lock systems. The security system can analyze the behavior patterns of family members and visitors. Once abnormal behavior (such as sudden intrusion, wandering, etc.) is detected, the system will immediately trigger an alarm and send relevant information to family members or the police. The camera can monitor the home environment 24/7 without any blind spots, ensuring home safety. Combined with AI image recognition technology, the system can accurately recognize targets in complex environments, such as objects at night or behind obstructions.

3.2.3 AI in whole house customized furniture design

By utilizing AI machine learning algorithms, designers can analyze user activity, shopping history, browsing his-

tory, and other data on social media to understand users' aesthetic preferences, functional requirements, and budget constraints. This personalized analysis helps designers provide customized design solutions for users. Combining AR technology, consumers can see the actual effect of furniture in their own homes through mobile applications before purchasing. This immersive experience helps consumers to more intuitively feel the design effect and reduce the uncertainty of purchasing decisions. AI can automatically design room layouts based on users' room size, shape, and furniture needs. This automated design not only improves design efficiency, but also ensures that furniture is coordinated with the overall style and space utilization of the room.

Taking the whole house customized smart wardrobe of a certain smart home brand as an example, the wardrobe fully utilizes AI technology in the design stage. Firstly, by analyzing users' purchase records, lifestyle habits, and aesthetic preferences through big data, AI can assist designers in generating preliminary design solutions that meet users' personalized needs. These solutions not only consider the basic functions of the wardrobe, such as the allocation of storage space and the classification of clothing storage, but also incorporate personalized elements for

users, such as color matching and material selection.

The components of a smart home security system currently consist of an access control system, a surveillance system, and an alarm system; Traditional surveillance and alarm systems have some drawbacks, such as hackers cracking the surveillance system, and most of the alarm systems can only alert the crowd and cannot do self-service to handle emergencies [9]. The security of the system can be greatly improved by introducing machine learning methods into the smart home security system (Figure 1 and Figure 2).



Fig.1. Access control system [9]



Fig.2 Surveillance System [9]

On the other hand, Unsupervised learning can adjust its parameters and structure in response to changes in the external environment, significantly enhancing flexibility [8]. When applied to smart home security systems, this improves self-learning capabilities and lays a solid foundation for future system optimizations and upgrades. In smart access control systems, both supervised and unsupervised learning methods can be employed for clustering

analysis of incoming and outgoing individuals. By comparing data within a database, the system can store and back up information on new visitors while occasionally updating their details.

Machine learning techniques can replicate human lifestyles and establish physiological models to simulate behavioral patterns. This alignment allows the security system to better match human habits. In smart home security,

users can input their voices, enabling machine learning algorithms to recognize family members and understand their spoken intent to carry out appropriate tasks [8]. Beyond voice recognition, image recognition plays a crucial role: if an unfamiliar image is detected, the alarm system activates, ensuring the safety of both family members and property. Additionally, smart simulation can create practical learning models and tools, enhancing knowledge accumulation in smart security and improving system intelligence. Smart simulations require pre-defined models that accurately replicate various scenarios and incorporate target objects, allowing for the forecasting of all possible outcomes. Once successful, these simulations can be implemented in real-world scenarios for quick integration.

By leveraging deep learning and computer vision technologies, smart home systems can analyze and recognize unstructured data, facilitating the interpretation of users' multi-modal information, such as voice, gestures, and facial expressions. This leads to improved human-computer interaction; for example, Apple's Siri, Xiaomi's Xiao Ai, and Baidu's Duer enable users to control smart devices via voice commands, while smart mirrors can respond to gestures or facial expressions. In some cases, home appliances can even be controlled using heart rate or brainwave signals.

In intelligent decision-making, autonomous adversarial strategies predict potential threats through data analysis, simulating interference and control while calculating probable outcomes for better counter-strategies. By collecting data on various appliances—such as energy consumption, temperature, humidity, and usage duration—the system can automatically adjust lighting, air conditioning, curtain timings, and robotic vacuum schedules based on user habits. In smart alarm systems, intelligent decision-making analyzes and identifies alarm triggers, enabling prompt autonomous responses that mitigate risks. This human-like functionality minimizes the need for manual intervention, saving users time and alleviating tedious tasks. The interrelated components of access control, surveillance, and alarm systems fortify the integrity of the entire security setup, and seamless interconnectivity between them is essential for stability [9]. By employing machine learning methods—including supervised and unsupervised learning, intelligent simulation, and smart decision-making—traditional home systems can undergo fundamental transformations. This evolution supports the development of modern smart cities, creating a safe, comfortable, and harmonious living environment for residents.

4. Conclusion

This article has delved into the application of AI and VR

technologies in the field of smart homes, analyzing how these technologies are transforming modern home life by enhancing home automation, enriching living experiences, and optimizing energy management. Through the analysis of specific application cases such as smart thermostats, intelligent lighting, and smart security systems, the article has demonstrated the immense potential of AI and VR technologies in smart home design, home entertainment, and remote monitoring. With continuous technological innovation and interdisciplinary collaboration, it is foreseeable that smart home systems will become more intelligent, secure, and user-friendly.

Looking ahead, the integration of AI and VR technologies will propel smart homes towards a higher level of automation and intelligence. On one hand, through deep learning and big data analysis, smart home systems will be able to predict user needs more accurately, achieving more precise personalized services. On the other hand, with the popularization of communication technologies such as 5G and the IoT, the interconnectivity between smart home devices will become more seamless, providing users with a more integrated smart living experience. At the same time, stricter standards and regulations need to be established to ensure the security and privacy of user information. Additionally, user education and training will become crucial to help users better understand and utilize smart home technology for its maximum benefit.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

References

- [1] Zhang Jiasheng, Li Guangyao. Research on Smart Home Security Systems Based on Machine Learning Methods. *Furniture & Interior Decoration*, 2021, (04): 20-22. DOI: 10.16771/j.cn43-1247/ts.2021.04.006.
- [2] Li Bingchen, Wang Longliu, Wen Jie. A Brief Discussion on the Current Status and Practical Design Applications of Smart Home Systems. *Green Construction and Intelligent Buildings*, 2023, (06): 49-53.
- [3] Zhang Heng, Wu Zhilin. Preliminary Exploration of Multifunctional Integration Design of Smart Small Appliances and Traditional Furniture. *Footwear Technology and Design*, 2024, 4(14): 169-171.
- [4] Zhu Shilong. Development and Application of Smart Homes. *Communications World*, 2018, (09): 238-239.
- [5] Zhang Siyi, Zhang Chungan, Gao Yang, Yu Shiting. Design of Voice-Controlled Smart Home Systems. *Electronic Production*, 2024, (09): 97-99+89.
- [6] Li Mengna. One-Click to Start: Opening «Smart Life» with Smart Home. *Ulanqab Daily*, 2024, (08): 2.

[7] Shi Yehui, Liu Jianbo, Wang Lizhong, Yu Shihao, Zhang Lanhang, Miao Tiantian. Implementation of Indoor Air Quality Detection and Control System for Smart Homes. *Tonghua Normal University Journal*, 2024, (08): 9-16.

[8] Zhang Xiaoliang, Hong Yaling. Architecture, Key Technologies, and Development of Smart Home Security

Systems. *China High-Tech Enterprise*, 2023, (07): 40-42+68. DOI: 10.13535/j.cnki.10-1507/n.2023.07.07.

[9] Wu Shaozhen, Wu Xiaowei. Application and Prospects of Artificial Intelligence Technology in Home Security Systems. *Network Security Technology and Application*, 2024, (04): 122-124.