Comparative Analysis of Augmented Reality, Mixed Reality, and Virtual Reality for Controlling Appliances Based on Parameters

Areej Mazhar[1], Maria Arooj[2], Rimsha Arshad[3]
[1,2,3]Department of Computer Science, University of Engineering and Technology, Lahore-Pakistan
[1] areejmazhar837@gmail.com, [2]mariaarooj.dev@gmail.com, [3]rimsha.arshad462@gmail.com

Abstract*– This paper offers a comparative assessment of home assistant, mixed reality, and augmented reality technologies for managing household appliances via a single control panel interface. The introduction of cutting-edge technology has become crucial for improving user comfort and experience with the rise of smart home systems. By superimposing digital content over the actual world, augmented reality allows users to interact with virtual aspects. Conversely, mixed reality allows for more immersive experiences by blending the virtual and actual worlds flawlessly. Home assistants that provide voice-activated control over different smart devices in a home include Google Assistant, Apple HomeKit, Amazon Alexa, and Apple HomeKit. In this study, we examine these technologies' usability, functionality, and user satisfaction with regard to home appliance control through a centralized control panel. We examine elements including responsiveness, accuracy, ease of setup, and compatibility with various appliances. We also evaluate each technology's overall user experience, perceived ease, and user preferences. We seek to determine the benefits and drawbacks of AR, MR, and home assistant-based control panels through user research and tests. The comparison investigation yielded insights that can help manufacturers and developers create smart home control systems that are easier to use and more effective. In the end, our research opens the door for more smooth integration of technology into day-to-day living and advances human-computer interaction in the context of smart home environments. The study also looks at how each technology can affect user security and privacy, taking into account things like data collecting, sharing, and security precautions. Gaining an understanding of these elements is essential to guaranteeing user confidence and trust when implementing smart home technologies. In order to give useful information for consumers and industry stakeholders, we hope to address these concerns and offer a thorough assessment of the viability of AR, MR, and home assistant technologies for operating home appliances via a centralized control panel. In addition to user experience and interface design, data management, security, and privacy issues are all covered in detail in this study. Compatibility problems between various platforms and devices give rise to interoperability challenges, which can impede control panel systems' smooth operation and integration. Data protection, illegal access, and possible breaches are all covered under security and privacy concerns, which emphasizes the need for strong security measures to secure user data and uphold privacy rights.

***Keywords*– Augmented Reality, Mixed Reality, Virtual Reality and Home Assistant**

I. INTRODUCTION

SMART home technology has completely changed how we live and work, providing previously unheard-of levels of efficiency, convenience, and control over household systems and equipment. Several applications of the Internet of Things (IoT) concept have already been investigated, including smart appliances (Blanco-Novoa et al, 2020). Nowadays, consumers have an abundance of choices for remotely managing and keeping an eye on their houses thanks to the widespread usage of smart interfaces and networked equipment. Home assistant (HA) technology, mixed reality (MR), and augmented reality (AR) have become the most popular options among them, each with various features and capabilities. By superimposing digital data over the actual world, augmented reality allows users to interact with virtual aspects that improve their understanding of the physical world (Seigar et. al., 2021). By seamlessly merging the virtual and real worlds, mixed reality expands on this idea and creates more engaging and participatory experiences. Home assistants, like Google Assistant, Apple HomeKit, and Amazon Alexa, allow voice control over a range of smart devices in a home, giving users automation and hands-free ease (Chakraborty and D. ,2023). By superimposing digital data over the actual world, augmented reality allows users to interact with virtual aspects that improve their understanding of the physical world. By seamlessly merging the virtual and real worlds, mixed reality expands on this idea and creates more engaging and participatory experiences (Wang and N., 2023). Home assistants, like Google Assistant, Apple HomeKit, and Amazon Alexa, allow voice control over a range of smart devices in a home, giving users automation and hands-free ease. The decreasing cost of AR/MR commercialization as a result of these advancements has attracted the attention of new customers and industries that are implementing Industry 4.0 and Industrial IoT paradigms to change their business operations (Blanco-Novoa et. al., 2020).

Advancements in technology inside AR and MR contexts have enabled interactive visualizations of hitherto undiscovered virtual and real-world amalgamations (Papadopoulos et at 2021). Similar to this, customers may see and interact with virtual representations of their smart home equipment within their physical surroundings by using mixed reality technologies to create immersive home automation experiences. (Jaivignesh, et. al., 2022).

The possibility of using these technologies to manage household appliances through a centralized control panel interface has attracted more attention in recent years. HCI is the process of collaboration and communication between people and machines (Kim et. al., 2021). The way people carry out daily jobs and process historical and cultural information has been drastically altered by utilizing immersive realities and the UCSD (Papadopoulos et. al., 2021). By providing consumers with a single platform to monitor and operate many appliances and systems, these interfaces aim to simplify the management of smart home equipment. The usefulness, applicability, and effectiveness of control panels based on AR, MR, and home assistants in this situation, however, have not yet been well investigated and comprehended (Stark et. al., 2020)

By analyzing the benefits, drawbacks, and implications of AR, MR, and home assistant technologies for managing household appliances through a centralized control panel, this comparative analysis aims to close this gap (Bermejo Fernandez, et al 2021). By conducting a thorough assessment of several aspects like usability, functionality, security, privacy, user experience, and data management, we hope to offer insightful information on how well these technologies work in actual smart home settings.

The goal of this study is to educate consumers, legislators, and industry stakeholders on the advantages and disadvantages of deploying smart home solutions by illuminating the potential and difficulties of AR, MR, and home assistant-based control panels. Our research will ultimately lead to the development of more effective and user-cantered smart home solutions, opening the door for a more smooth and seamless integration of technology into everyday life.

An additional layer of automation and intelligence is added to smart home ecosystems through the incorporation of sensors. Many elements of the home environment, including temperature, humidity, occupancy, and ambient light levels, can be detected by sensors placed throughout. Smart systems are able to adjust appliance settings to match user preferences and environmental circumstances by gathering and evaluating this data.

Users can adjust the appliance's settings to suit their tastes and the current climatic conditions. For instance, a smart thermostat with occupancy sensors can change the temperature of a room according to the presence or absence of a person.

In a similar vein, lighting controls can adjust automatically to brighten or dim depending on the time of day and amount of natural light, improving both energy efficiency and comfort. Nevertheless, direct monitoring and management of Internet of Things devices and applications is typically the extent of interactions with these smart devices. In smart environments, more complicated automated routines and procedures are rarely implemented, despite their considerable potential for increased comfort and efficiency (Seigar et. al., 2021).

II. LITERATURE REVIEW

In 2020, user experience assessment measures were combined with a visual analytics system for data on bee drifting, as well as Augmented Reality (AR) technology, demonstrated by Microsoft HoloLens with the Windows desktop interface. In a noteworthy study, the benefits of augmented reality were highlighted by contrasting user experiences with paper-based instructions for Rubik's Cube task help. These advantages included increased satisfaction, shorter completion times, better success rates, and lower stress levels. The significance of taking aesthetics and human-centered AR design into account was carefully noted. (Seigar et al 2021).

Conducting a thorough assessment of user experiences and preferences across different control scenarios requires the use of a systematic methodology. Evaluating user choices and actions in various control environments is crucial. This entails assessing control strategies for activities including device connections, boombox controls, speakers, lighting, blinds, thermostats, and video displays, as well as gesture and speech navigation. (Wang and N., 2023).

Remote appliance control may be achieved by using an ESP32 microcontroller that is Wi-Fi-based, and AR content generation and interaction can be facilitated using Unity3D and Vuforia SDK. Data supplied to a Blynk server allows for real-time monitoring. Conventional Internet of Things home automation solutions sometimes lack a compelling control interface and an interactive environment. Users can influence the Internet Things (IoT) devices by employing 3D items in their physical surroundings by integrating interactive material that overlays on real-world objects through the use of augmented reality (AR) (Jaivignesh et. al., 2022).

III. METHODOLOGY

We have three of the articles in which we compared different IoT application protocols and suggest which protocol perform better in which article.

A) Size of Message and Overhead

Networked Mixed Reality Framework: Emphasizes transmission efficiency and the size of HTTP POST packets, which are 95 bytes (Blanco-Novoa et. al., 2020).

Holo-Flows: Talks about data transfer between sensors, actuators, and control systems as well as Internet of Things procedures (Seigar et. al., 2021).

Augmented reality-based Internet of Things switch: Details the ESP32 microcontroller's specs to calculate message size and overhead (Chakraborty and D., 2023).

B) Power Usage and Necessary Resources

Networked Mixed Reality Framework: Takes IoT device resource efficiency and power usage into account (Blanco-Novoa et. al., 2020).

Holo-Flows: Highlights how power consumption and resource allocation are affected by MR technology and Internet of Things devices (Seigar et. al., 2021).

Augmented reality-based Internet of Things switch: gives details on the ESP32's resource and power needs (Chakraborty and D., 2023).

C) Latency and Bandwidth

Networked Mixed Reality Framework: Examines sensor data transmission delay and its impact on bandwidth (Blanco-Novoa et al, 2020).

Holo-Flows: Discusses several IoT process modeling techniques that could affect latency and bandwidth. (Seigar et al 2021).

Augmented reality-based Internet of Things switch: explains the ESP32's operating frequency, interfaces, and how they affect latency and bandwidth (Chakraborty and D., 2023).

D) Reliability and QoS

As stated in the paper "Networked Mixed Reality Framework for the Internet of Things," reliability is the capacity of the Mixed Reality Control Panel (MRCP) system to continue operating and functioning consistently when communicating with IoT devices. This involves making certain that the system runs without hiccups or unanticipated malfunctions, giving consumers solid experience while managing Smart Parking Meters and Smart Locks via the MRCP application. (Blanco-Novoa et. al., 2020).

The document's use of the term QoS (Quality of Service) refers to the degree of functionality and service quality that the MRCP system provides while overseeing Internet of Things devices. It includes elements like reactivity, effectiveness, and general user satisfaction with the system's capacity to easily operate and communicate with Internet of Things devices. The paper probably goes into how the MRCP system upholds strict QoS requirements to improve user experience and guarantee dependable operation of mixed reality-enabled IoT devices (Blanco-Novoa et. al., 2020).

The study indicates a dependable system by emphasizing improving user experience and lowering the technical skill needed to create IoT procedures. Holo-Flows, is to give end users a simpler and more intuitive way to model Internet of Things (IoT) processes using Mixed Reality (MR) technology. This can improve the dependability of IoT systems. (Seigar et. al., 2021).

Although Quality of Service (QoS) is not mentioned specifically in the study, the emphasis on boosting the user experience, lowering the need for technical skills, and improving the modeling of IoT processes using Holo-Flows subtly raises the possibility of improving QoS for IoT applications (Seigar et. al., 2021).

Achieving high QoS and dependability in IoT systems is crucial to guaranteeing smooth operation, accurate data, and user happiness. IoT platforms may improve safety, maintenance, and monitoring duties by using technologies like augmented reality and virtual reality. This will eventually improve dependability and quality of service in complicated contexts. (Chakraborty and D., 2023).

E) Interpretability

The idea of interoperability does not seem to be covered. In order to integrate IoT devices into everyday life using a mixed reality interface, the document focuses on the creation of the Mixed Reality Control Panel (MRCP) system (Blanco-Novoa et. al., 2020).

Holo-Flows enables the establishment of many connectivity patterns, including conditional, direct, and actuator-actuator connections, all of which necessitate device compatibility. This promotes interoperability within Internet of Things operations (Seigar et. al., 2021).

In order to create sophisticated IoT solutions that serve a wide range of applications, including energy monitoring, device control, environmental monitoring, and maintenance chores in harsh work environments, interoperability must be achieved. Interoperability may be improved to produce creative and effective solutions for a range of sectors by combining technologies like augmented reality and virtual reality with Internet of Things platforms. (Chakraborty and D., 2023).

F) IoT usage

The Mixed Reality Control Panel (MRCP) system, an open-source, cross-platform, vendor-neutral mixed reality program made to communicate with headless Internet of Things devices, is the suggested remedy. The document describes how the mixed reality interface may add more smart features and improve the user experience with various Internet of Things devices. It also tests the MRCP system with Smart Parking Meters and Smart Locks. (Blanco-Novoa et. al., 2020).

IoT devices become first-class citizens in the modeling process when users virtually connect actual IoT devices to simulate processes between sensors and actuators (Seigar et. al., 2021). Holo-Flows demonstrates a user-friendly approach to IoT usage by enabling users to explore the IoT environment and design sophisticated IoT processes without requiring significant technical competence or programming experience (Seigar and R., 2021).

G) Standardization

Holo-Flows facilitates standardization in the development of intricate processes involving sensors, actuators, and gateways by offering an organized method for modeling IoT processes. This improves consistency and interoperability in IoT settings (Seigar et. al., 2021).

The problems of device heterogeneity, data silos, and security flaws in IoT installations are addressed in part by standardization initiatives. Increased scalability, stability, and interoperability of IoT solutions may result in improved system performance and user experiences by adhering to established protocols and frameworks (Chakraborty and D., 2023).

H) Security

Several steps may be taken to protect the Mixed Reality Control Platform (MRCP) from unwanted users:

User Authentication: Give the MRCP application a strong user authentication mechanism. To guarantee that only those with permission may access the system, this might involve user role management, multi-factor authentication, and secure login procedures. (Blanco-Novoa et. al., 2020).

Encryption: To protect the data sent and stored inside the MRCP system, make use of robust encryption techniques. This can involve encrypting user credentials, data that is at rest, and communication methods. (Blanco-Novoa et. al., 2020).

Strict access control procedures should be put in place to guarantee that users may only access the features and information they are permitted to use. Least privilege guidelines and role-based access restrictions may be involved in this (Blanco-Novoa et. al., 2020).

Secure Communication: Make sure that secure channels, including HTTPS and secure sockets, are used for all communication between the MRCP application, devices, and network components. (Blanco-Novoa et. al., 2020).

Frequent Security Audits: To find and fix any possible security flaws in the MRCP system, perform frequent security audits and vulnerability assessments. (Blanco-Novoa et. al., 2020).

Firmware and Software upgrades: To reduce potential vulnerabilities, keep the MRCP devices' firmware and software components up to date with the most recent security patches and upgrades. (Blanco-Novoa et. al., 2020).

Physical Security: Put in place physical security measures to keep others from accessing or altering the MRCP equipment (Blanco-Novoa et al, 2020).

To safeguard sensitive data and guarantee the integrity and confidentiality of data sent between sensors, actuators, and control systems, security measures are crucial in Internet of Things contexts. (Seigar et. al., 2021).

Encryption and secure communication protocols must be included in Internet of Things procedures in order to preserve data privacy and defend IoT systems against potential intrusions or cyberattacks (Seigar et. al., 2021).

The IoT switch project intends to improve the system's overall security posture by combining security factors such as encrypted communication channels, secure authentication tokens, and access control mechanisms. These settings aid in user authentication, data encryption, and preventing illegal access to IoT devices and network infrastructure. (Chakraborty and D., 2023)

In order to preserve the efficacy of security settings in IoT installations, the paper emphasizes the importance of ongoing monitoring, vulnerability assessments, and security upgrades. To ensure the resilience and integrity of the IoT system against developing cyber threats, regular security audits and risk assessments are crucial for identifying and addressing any security vulnerabilities. (Chakraborty and D., 2023).

V. DISCUSSION

Interoperability Issues: In order to enable smooth communication and interoperability between AR and IoT devices, researchers must concentrate on creating standardized protocols and frameworks. This might entail investigating current protocols and standards, such MQTT or OPC UA, and creating new ones specifically for AR-enhanced Internet of Things devices (Chakraborty and D., 2023).

Advanced Data Management: Creating effective data processing and storage systems that can manage the massive amounts of data produced by AR and IoT devices is essential to addressing data management issues. Researchers might investigate methods to optimize data handling in AR-enhanced IoT systems, such as distributed data management, cloud computing, and edge computing (Chakraborty and D., 2023).

Hardware Restrictions: To get beyond hardware restrictions in AR and IoT devices, researchers should look at improvements in hardware technologies, such as sensors, CPUs, and displays. This might entail creating hardware components that are energy-efficient and lightweight for use in AR applications and Internet of Things deployments.

Optimal Techniques for AR-Powered IoT Devices: To design, develop, and implement AR-enhanced IoT systems, researchers must create and share best practices. This entails investigating practical approaches for fusing AR with IoT while guaranteeing the systems' usability, scalability, and security (Chakraborty and D., 2023), (Blanco-Novoa et. al., 2020), (Seigar et. al., 2021).

Less Reliance on Vendor-Specific Solutions: Scholars might endeavor to create open-source tools and platforms that encourage compatibility and interoperability across various IoT apps and devices. In order to create shared standards and advance vendor-neutral solutions, this entails promoting cooperation between industry players, standardization organizations, and research groups (Blanco-Novoa et. al., 2020), (Seigar and R., 2021), (Chakraborty and D., 2023).

Improving User Experience: By creating user-friendly modeling tools, reducing the amount of technical knowledge needed to communicate with IoT devices, and creating intuitive interfaces, researchers may concentrate on enhancing the user experience of AR-enhanced IoT systems. This includes designing AR-enhanced Internet of Things apps iteratively, collecting user input, and performing usability tests.

VI. CONCLUSION

In conclusion, our comparison study has shown how complex it might be to integrate AR, MR, and VR with IoT systems. Through investigating many modules, including IoT use, standardization, interoperability, latency, and bandwidth, we have acquired significant understanding of the possible advantages and difficulties associated with this integration. Future research and interdisciplinary cooperation will be necessary to fully exploit the promise of AR-enhanced IoT systems across a range of sectors.

REFERENCES

[1]. Blanco-Novoa, Ó., Fraga-Lamas, P., A. Vilar-Montesinos, M. and Fernández-Caramés, T.M., 2020. Creating the internet of augmented things: An open-source framework to make iot devices and augmented and mixed reality systems talk to each other. Sensors, 20(11), p.3328.

[2]. Seiger, R., Kühn, R., Korzetz, M. and Aßmann, U., 2021. HoloFlows: modelling processes for the Internet of

Things in mixed reality. Software and Systems Modeling, 20(5), pp.1465-1489.

[3]. CHAKRABORTY, D., 2023. IoT switch based on Augmented Reality (Doctoral dissertation, University of Technology).

[4]. Blanco-Novoa, Ó., Fraga-Lamas, P., A. Vilar-Montesinos, M. and Fernández-Caramés, T.M., 2020. Creating the internet of augmented things: An open-source framework to make iot devices and augmented and mixed reality systems talk to each other. Sensors, 20(11), p.3328.

[5]. Wang, N., 2023. Evaluating User Preferences for Interaction for Single User Cross Reality Transition of 3D Virtual Objects.

[6]. Jaivignesh, R., Janarthanan, R.D. and Gnanalakshmi, V., 2022, August. Smart Home Automation using Augmented Reality and Internet of Things. In Journal of Physics: Conference Series (Vol. 2325, No. 1, p. 012003). IOP Publishing.

[7]. Papadopoulos, T., Evangelidis, K., Kaskalis, T.H., Evangelidis, G. and Sylaiou, S., 2021. Interactions in augmented and mixed reality: an overview. Applied Sciences, 11(18), p.8752.

[8]. Kim, J.C., Laine, T.H. and Åhlund, C., 2021. Multimodal interaction systems based on internet of things and augmented reality: A systematic literature review. Applied Sciences, 11(4), p.1738.

[9]. Stark, E., Kučera, E., Haffner, O., Drahoš, P. and Leskovský, R., 2020. Using augmented reality and internet of things for control and monitoring of mechatronic devices. Electronics, 9(8), p.1272.

[10]. Bermejo Fernandez, C., Lee, L.H., Nurmi, P. and Hui, P., 2021, October. Para: Privacy management and control in emerging iot ecosystems using augmented reality. In Proceedings of the 2021 International Conference on Multimodal Interaction (pp. 478-486).

[11]. Zhang, Z., Wen, F., Sun, Z., Guo, X., He, T. and Lee, C., 2022. Artificial intelligence-enabled sensing technologies in the 5G/internet of things era: from virtual reality/augmented reality to the digital twin. Advanced Intelligent Systems, 4(7), p.2100228.

[12]. Jackson, B., Lor, L. and Heggeseth, B.C., 2024. Workspace Guardian: Investigating Awareness of Personal Workspace Between Co-Located Augmented Reality Users. IEEE Transactions on Visualization and Computer Graphics.

[13]. Jo, D. and Kim, G.J., 2016. ARIoT: scalable augmented reality framework for interacting with Internet of Things appliances everywhere. IEEE Transactions on Consumer Electronics, 62(3), pp.334-340.

[14]. Rashid, Z., Melià-Seguí, J., Pous, R. and Peig, E., 2017. Using Augmented Reality and Internet of Things to improve accessibility of people with motor disabilities in the context of Smart Cities. Future Generation Computer Systems, 76, pp.248-261.

[15]. Phupattanasilp, P. and Tong, S.R., 2019. Augmented reality in the integrative internet of things (AR-IoT): Application for precision farming. Sustainability, 11(9), p.2658.

[16]. Seo, D.W., Kim, H., Kim, J.S. and Lee, J.Y., 2016. Hybrid reality-based user experience and evaluation of a context-aware smart home. Computers in Industry, 76, pp.11-23.

[17]. White, G., Cabrera, C., Palade, A. and Clarke, S., 2019. Augmented reality in IoT. In Service-Oriented Computing–ICSOC 2018 Workshops: ADMS, ASOCA, ISYyCC, CloTS, DDBS, and NLS4IoT, Hangzhou, China, November 12–15, 2018, Revised Selected Papers 16 (pp. 149-160). Springer International Publishing.

[18]. Makolkina, M., Koucheryavy, A. and Paramonov, A., 2017. The models of moving users and IoT devices density investigation for augmented reality applications. In Internet of Things, Smart Spaces, and Next Generation Networks and Systems: 17th International Conference, NEW2AN 2017, 10th Conference, ruSMART 2017, Third Workshop NsCC 2017, St. Petersburg, Russia, August 28–30, 2017, Proceedings 17 (pp. 671-682). Springer International Publishing.

[19]. Subakti, H. and Jiang, J.R., 2018, July. Indoor augmented reality using deep learning for industry 4.0 smart factories. In 2018 IEEE 42nd Annual Computer Software and Applications Conference (COMPSAC) (Vol. 2, pp. 63-68). IEEE.

[20]. Jaivignesh, R., Janarthanan, R.D. and Gnanalakshmi, V., 2022, August. Smart Home Automation using Augmented Reality and Internet of Things. In Journal of Physics: Conference Series (Vol. 2325, No. 1, p. 012003). IOP Publishing.