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UNVEILING THE POTENTIAL OF MIXED REALITY: OPPORTUNITIES, CHALLENGES AND FUTURE PROSPECTS

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ABSTRACT

Mixed Reality (MR) is an advancing technology with the potential to revolutionize the realm of information and communication technology (ICT). By combining the strengths of virtual reality (VR) and augmented reality (AR), MR creates an immersive and interactive user experience. Its applications in ICT are extensive, encompassing education, training, entertainment, and healthcare. However, MR is a relatively new technology and faces numerous challenges that must be addressed before its full realization. Many technical aspects and requirements remain unclear. This paper aims to emphasize the applications of mixed reality in the ICT industry. It provides an overview of MR in education, explores opportunities, challenges, and future prospects. Additionally, the authors discuss the opportunities and challenges in MR development. MR technology is widely utilized in art and design, particularly in product design, display design, and interactive design. The paper concludes by summarizing the future trends of mixed reality technology, considering market and industry factors. While the application of mixed reality technology in the field of art design gains increasing attention from industry, it still lacks sufficient attention from the academic community.
Keywords: *Augmented Reality (AR), Immersive Technology, Mixed Reality (MR), Virtual Reality (VR),User Experience*

1. INTRODUCTION

Mixed Reality (MR) is the blending of virtual reality (VR) and augmented reality (AR) technologies, resulting in a spectrum that combines real-world elements with virtual objects orenvironments. It encompasses a range of experiences that enable users to interact with and manipulate both physical and digital elements simultaneously. The utilization of information and communication technology (ICT) has greatly enhanced the quality of educational programs

provided by institutions. In this rapidly changing and technologically advanced era, educators must adapt to the inventions and advancements in order to cater to the needs of the current generation of students [1]. The development of new technologies has facilitated the creation of applications that serve as decision-making tools for solving daily life problems [2]. MR is an emerging technology that is being extensively researched by major tech companies and academic institutions. The concept of "mixed reality" brings digital objects closer to becoming integrated into physical reality. The user remains connected to the real world while also interacting with virtual world elements and augmented reality objects. By combining these elements, VR enables user interaction [3]. In the 1960s, various AR and VR devices were invented, such as the Sensorama VR machine [4] and the Sword of Damocles AR machine [5]. Since then, AR and VR have evolved with advancements in sensors, displays, and computers. Recently, MR has emerged, allowing us to interact with virtual/digital objects in real environments. Reality technologies can be utilized for different purposes using various technological tools. They can support both distance and traditional education. Reality technologies can be categorized into three areas: virtual reality, augmented reality, and mixed reality [6]. Every few decades, a new technology emerges and revolutionizes the way we conduct our daily lives. The telephone enabled cross-continental communication, while the internet made our modern world possible. Soon, everyone will be curious about the key features of mixed reality technology and the benefits it offers to individuals and businesses. According to Statista, the global market for augmented reality (AR), virtual reality (VR), and mixed reality (MR) reached a total of 28 billion U.S. dollars in 2021 and is projected to exceed 250 billion U.S. dollars by 2028. Businesses are rapidly adopting mixed reality technologies in their day-to-day operations.

Mixed Reality combines the most desirable elements of virtual reality and augmented reality, seamlessly integrating digital content with the real world. This fusion creates captivating and interactive experiences that have the potential torevolutionize how we work, learn, play, and interact with our surroundings. In this article, the authors delve into the realm of immersive technologies and dissect the distinguishing features of mixed reality that set it apart from AR and VR technologies. Mixed reality, as its name suggests, blends physical reality with digital material, resulting in a user experience known as mixed reality that enables interaction among real-world and virtual elements. Unlike virtual reality, which immerses users in a completely digital environment, and augmented reality, which overlays digital content onto the physical world, mixed reality combines both digital and physical environments. While mixed reality is sometimes considered a form of augmented reality, its unique ability to facilitate interaction between physical and digital elements places it further along the spectrum of virtuality, with physical reality on one end and fully virtual reality on the other. Mixedreality is also referred to as Extended Reality (XR) or hybrid reality, denoted by the acronym's MR or XR. To map the user's actual surroundings, headgear with tracking capabilities is utilized to monitor the user's gaze and hand movements. The software then employs deep learning techniques to align digital information with specific sections ofthe mapped environment.

2. WHAT IS MIXED REALITY?

Practical learning still faces limitations in online education, highlighting the need to integrate Augmented Reality (AR) and Virtual Reality (VR) technologies to enhance its effectiveness. This integration is commonly known as mixed reality (MR) [3]. The incorporation of MR technologies in teaching offers new opportunities to merge practical experiences with theoretical contexts [7]. This evolving approach, referred to as Extended Reality (XR), encompasses various immersive technologies and future digital advancements, extending beyond the MR continuum. XR serves as a dynamic and culturally-responsive "medium" that enables tailored, flexible, and adaptable user experiences based on user-centric learning design strategies and pedagogy [8]. Recent research expands the traditional view of the digital continuum proposed by Milgram and Kishino [10], encompassing a diverse range of sensorial dimensions, technological tools, networked intelligent platforms, and embodied user engagement modes within MR environments. This interconnected ecosystem and perceptual modes create rich learning ecosystems [11,12]. Mixed reality (MR) refers

to the convergence of virtual reality (VR) and augmented reality (AR), blending the physical and digital realms to enable users to interact with virtual objects in a realistic manner. MR technology utilizes specialized hardware and software to create immersive experiences that find

applications in various fields, including training, education, product design, customer service, and retail. While MR has the potential to revolutionize technology interaction and task performance, it alsopresents challenges such as cost, compatibility, user adoption, and legal and ethical considerations. In the ICT industry, MR holds significant promise for transforming technology interaction and task execution. Some potential applications of MR inthe ICT industry include:

i. Training and education: MR can be used to create immersive training simulations for tasks such as equipment maintenance or emergency response. This can be especially useful for industries where hands-on experience is necessary but dangerous or impractical to obtain.
ii. Product design and prototyping: MR can be used to visualize and test new product designs in a virtual nvironment, allowing designers to make changes and see the results in real-time.
iii. Customer service and support: MR can be used to provide remote assistance to customers, allowing technicians to see and interact with a customer's equipment as if they were physically present.
iv. Retail and marketing: MR can be used to enhance the shopping experience by allowing customers to visualize products in their own space before making a purchase.

The development of MR involves multiple research areas such as computer geometry, computer network, imaging processing, 3D modeling and rendering, speech recognition and motion recognition, etc. The advancement of all these research areas will benefit next generation MR devices which typically include space registration, hardware, facilities, space building, human- computer interaction as shown in Table 1.

Table 1: Composition of Mixed Reality (MR)

Composition of Mixed Reality	
Space registration	The coordinates of the virtual world and the real world corresponds, so that the virtual object and the real time form a correct spatial perspective relationship.
Hardware facilities	Mixed reality systems primarily involve hardware devices such as displays, computers, tracking cameras, and input devices.
Space building	Broadly speaking, a mixed reality space is the state of virtual objects in real space, the rules that objects follow, the relationships and interactions between them.
Human-computer interaction	Interaction between the user and the virtual object.

Source: Adopted from Chunfa et al., (2022)

3. APPLICATIONS OF MIXED REALITY

Mixed reality (MR) applications were ranked among the top 10 ICT technologies in 2020 [13]. Extensive research has been conducted on MR technology, resulting in the creation of various survey categories related to this technology. Some surveys have specifically included the MR component. MR, a technology that merges virtual reality (VR) and augmented reality (AR) elements, enhances user experiences through increased immersion and interactivity. As a result, MR finds applications across a wide range of industries and fields. The potential of MR in various domains is constantly expanding, with ongoing exploration of innovative applications. Here are a few examples ofthe main areas where MR is currently being utilized or holds the potential for utilization:

3.1 Education and Training

MR can be used to create immersive and interactive learning environments that engage students and improve their understanding of complex concepts. It can also be used to simulate real-world scenarios, such as surgeries and other procedures, to provide hands-on training to students in fields such as healthcare and engineering.

3.2 Entertainment

MR can be used to create immersive gaming experiences and enhance the viewing experience for sports and live events. It can also be used to create virtual tours and experiences that allow people to explore different parts of the world and historical sites without leaving their home.

3.3 Healthcare

MR can be used to create virtual medical simulations for medical and surgical training, rehabilitation, and therapy. Can also be used for the treatment of phobias and mental illnesses by providing a controlled and safe environment for patient.

3.4 Architecture and Construction

MR can be used to create virtual models of buildings and other structures to aid in the design, planning, and construction process.

3.5 Retail and Marketing

MR can be used to create virtual showrooms and product displays, allowing customers to explore and interact with products in a more engaging and interactive way.

3.6 Manufacturing and Industry

MR can be used to create virtual simulations of manufacturing processes and industrial systems to improve worker training, production efficiency, and maintenance procedures.

3.7 Tourism and Museums

MR can be used to create virtual tours and historical experiences, allowing people to explore different parts of the world and historical sites without leaving their home.

4. PROPOSE FRAMEWORK FOR MIXEDREALITY (MR)

Modern computers and portable devices now incorporate inputs, computing units, storage, and outputs into a single integrated system. The advent of laptops and smart devices has brought about significant changes in our lives, offering the convenience of compact size and lightweight design. However, mixed reality (MR) is set to revolutionize the computing landscape by shifting the burden of computing, storage, and numerous other functions to the edge and cloud [14]. A mixed reality (MR) framework refers to a collection of guidelines or principles used for the design and development of MR applications and experiences. Such a framework serves to ensure the effectiveness, efficiency, and user-friendliness of MR applications. Various frameworks have been proposed for MR, with specific components tailored to the intended usage of MR and the users' requirements. Nevertheless, some common elements that may be found in an MR framework include:

Hardware and software: a framework should specify the hardware and software requirements for MR, including any specialized equipment such as headsets or sensors.

i. **User interface**: a framework should specify how users will interact with MR content, including through gestures, voice commands, or other methods.
ii. **Content creation and management**: a framework should outline how MR content will be created and managed, including how it will be stored and accessed.
iii. **Data collection and analysis**: a framework should specify how data will be collected and analyzed to track user engagement and improve the MR experience.
iv. **User experience:** a framework should consider the overall user experience, including factors such as usability, accessibility, and user satisfaction.

Developing an MR application is complicated and a key issue in designing such an application is the increasing level of user interaction. There are three important features of any MR system: (1) combining the real-world object and the virtual object; (2) interacting in real-time; and (3) mapping between the virtual object and the real object to create interactions between them [15].

A study by Rokhsaritalemi et al. [16], proposes a comprehensive framework comprised of necessary components for MR applications, as shown in Figure 2. the first layer describes the components of MR applications; the second and third layers are about the architecture used to integrate these components; and the final layers include the application and UI layers [16]. This review can help researchers to develop better MR systems for manufacturing training that aids

industry workers in severe environments. Overall, a good MR framework should provide a clear set of guidelines and principles that can be used to design and develop MR applications that are effective, efficient, and user-friendly.

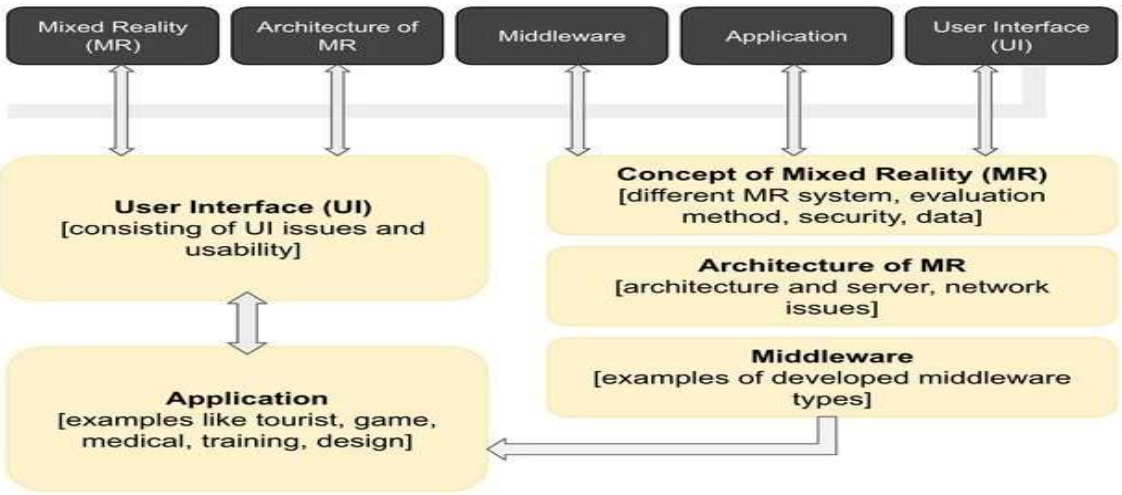


Figure 2. A Comprehensive Framework For Mixed Reality(MR) Applications

5. COMPARISON BETWEEN VIRTUAL REALITY (VR), MIXED REALITY (MR) AND AUGMENTED REALITY (AR)

Under the umbrella term of extended reality (XR), augmented reality (AR), virtual reality (VR), and mixed reality (MR) share a common realm of immersive technology. While each of them offers varying degrees of immersion, there exists a potential relationship that places them at the center of immersive tech. Augmented reality enhances real-world scenarios by overlaying digital content, serving educational, entertainment, and immersive purposes. It enriches a user's perception by augmenting their sensory experience. AR experiences typically rely on AR headsets, controllers, input devices, and gyroscopes. Examples of AR applications include Pokémon Go and Snap AR.Virtual reality, on the other hand, presents a complete digital replication of reality,embodying real elements through virtual avatars. As a fundamental concept behind the metaverse, virtual reality primarily focuses on facilitating virtual cross-border communication and fosteringsocial connections.

Mixed reality, as a hybrid of augmented and virtual reality, allows for the interaction of 3D objects with the physical environment and people. It can create visually deceptive elements within the user's surroundings, blurring the line between what is real and computer-generated. This emerging innovation is poised to gain significant traction in the upcoming years, particularly as more individuals rely on cloud networks and immersive devices for communication. Mixed reality (MR) encompasses the fusion of real and virtual worlds to deliver a unified, immersive experience that seamlessly integrates the physical and digital realms. Some notable features of mixed reality include:

i. **Real-time interaction:** MR allows users to interact with virtual objects in real-time, using gestures, voice commands, or other input methods.

ii. **Immersion:** MR can create a sense of immersion, as users feel like they are interacting with the virtual world as if it

were real.

iii. **Blending of physical and virtual:** MR blends the physical and virtual worlds, allowing users to see and interact with virtual objects in their real-worldenvironment.

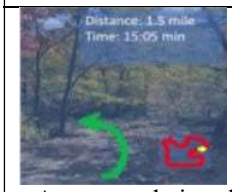
iv. **Enhanced reality:** MR can enhance the real world by overlaying virtual elements onto it, such as information or graphics.

v. **Portability:** MR can be accessed through various devices, including smartphones, tablets, and specialized headsets, which makes it portable and accessible.

vi. **Collaboration:** MR can facilitate collaboration by allowing multiple users to interact with the same virtual environment from different locations.

Mixed reality is a seamless corporation of augmented and VR. It can be very difficult to differentiate between the three. This paper also explores the wide world of mixed reality and lists the key features. Hence, here is a quick breakdown of the key differences between AR, VR, and MR as shown in Table 1.

Table 1. Comparison Between To Virtual Reality (VR), Mixed Reality (MR) And Augmented Reality (AR)

Features	Virtual Reality	Mixed Reality	Augmented Reality
Display device	Mostly using special headset or smart glasses	Headsets optional	Headsets optional
Display Example			
	 Augmented virtual map and direction	 Interactive virtual contents	 Virtual gaming
Image source	Computer graphics or real images produced by a computer	Combination of computer-generated images and real-life objects	Combination of computer-generated images and real-life objects
Environment	Fully digital	Both virtual and real-life objects are seamlessly blended	Both virtual and real-life objects are seamlessly blended
Working Environment	Indoors	Outdoor/Indoor Works best indoors	Indoors
Engagement	High	High	High
Presence	Feeling of being transported somewhere else with no sense of the real world	Feeling of still being in the real world, but with new elements and objects superimposed	Feeling of still being in the real world, but with new elements and objects superimposed

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Awareness	Perfectly rendered virtual objects that cannot be distinguished from real objects	Perfectly rendered virtual objects that cannot be distinguished from real objects	Virtual objects can be identified based on their nature and behavior, such as floating text that follows a user
Interaction	Joysticks and controller	Finger touch and tap interaction	Either controllers or gestures
Perspective	Virtual objects will change their position and size according to the user's perspective in the virtual world	Virtual objects behave based on user's perspective in the real world	Virtual objects behave based on user's perspective in the real world
Usage	Extensively used in games, education and training	Moderately used in games and training	Scarce usage

Consumer Adoption	Low due to high cost and complex hardware requirements	High due to low cost and ease of downloading application on mobile phones	Low due to high cost and complex hardware requirements
Immersive Experience	It provides a fully immersive experience driven by the virtual system.	It provides a more nuanced and well-rounded experience using high spec sensors.	It provides a partially immersive experience.
Capability	Not having see through capabilities	It's a package of see through capabilities	Having partial see through capabilities
Technological Setup	It is completely virtual	It is a hybrid version that includes both and adds the interaction between both	It has a mix of real world and virtual settings
Controls	The experience is controlled by the software	It can be partially controlled by use and software both	The user can control their presence in reality
Remote Collaboration	Yes	Yes	Yes
Co located Collaboration	No	Yes	Yes
Relationship (User-Virtuality)	Yes	Yes	Yes
Relationship (Reality-Virtuality)	No	Yes	No
Relationship (User-Reality)	No	Yes	Yes

Source: Adopted and adapted from McMillan et al., (2017), Ian & Hongzhi (2022)

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6. BENEFITS OF MIXED REALITY (MR)

Advancements in immersive mixed reality technology have opened up new avenues for both commercial and non-commercial sectors. Ideas that were once devised as sci-fi movies have slowly and gradually drifted into reality.

i. **Strong customer base:** Mixed reality combined with next-level AI can create unforgettable customer experiences at scale. Customers can experiment with something, try it on, or learn how to use it through instructional videos or virtual manuals in reallife.

ii. **Trustworthiness:** Trusted brands like Facebook, Apple, and Samsung are already investing in subsidiaries that will develop MR experiences for the general public. These initiatives are also funded heavily in doubt in the minds of consumers.

iii. **Increased concentration:** MR combines natural and digital elements in unexpected ways that keep people focused until their experience is over.

iv. **Hyper personalization:** No other form of media passes as more personal and engaging for customers than mixed reality. The individual immersed in a mixed reality scenario works with digital information more closely while in their physical world.

v. **Virtual demos for vendors:** If you are a B2B company, you can provide holographic devices to your client for virtual walkthroughs of the product, which showcase features, modules, applications, and results in the customer's living space.

vi. **Reduced mishaps:** Using MR technology as an adaptive training simulator for dangerous scenarios such as mining, archaeology, or mountain climbing reduces casualties and accidents.

vii. **Conducive learning:** Mixed reality's cousin, augmented reality has successfully broken the outdated barriers to education and provides an experiential environment for students to learn, brainstorm, and interact.

7. OPPORTUNTIES OF MIXED REALITY (MR)

The field of education and training presents a significant opportunity for mixed reality (MR) in the realm of ICT. MR has the potential to revolutionize learning by creating immersive and interactive environments that actively engage students and enhance their comprehension of complex concepts. Moreover, MR can simulate real-world scenarios, enabling hands-on training forstudents in disciplines like healthcare and engineering. The advancement of mixed reality (MR) technology opens up numerous prospects across diverse industries. MR offers the potential toimprove efficiency by streamlining tasks and processes, thereby reducing time and effort required for completion. In the realm of training and education, MR can provide immersive and realistic simulations, enhancing the learning experience. Furthermore, MR empowers users to work more efficiently and effectively, thereby boosting productivity. Additionally, MR can enhance customer service and support, leading to heightened levels of customer satisfaction. MR can also be leveraged to create simulations for tasks that are perilous or unfeasible to perform in real-world settings, thereby enhancing worker safety. Moreover, MR unlocks new business opportunities by enabling the provision of innovative products and services. From a creative standpoint, MR serves as a valuable tool, fostering new ideas and novel problem-solving approaches. Furthermore, MR facilitates communication and collaboration among team members, transcending geographical boundaries.

8. CHALLENGES OF MIXED REALITY (MR)

and the enhancement of haptic and audio technologies. Additionally, the cost and availability of MR devices present a significant hurdle, as they are currently relatively expensive and not widely accessible. Furthermore, the challenge lies in effectively integrating epistemological and technological innovations into authentic, contextual, and tangible practices while maintaining a balance with real-world, non-

technology mediated experiences. This becomes even more pronounced in the face of global pandemics, where teachers face increased difficulties in connecting remote teaching with practical content. In such scenarios, the utilization of MR in remote teaching has been perceived as beneficial by learners, as it enables a realistic experience and enhances understanding of presented theory when compared to traditional teaching methods. Addressing these challenges is crucial for unlocking the full potential of MR in education and training, as it requires overcoming technical, financial, and pedagogical obstacles to ensure seamless integration and meaningful learning experiences.

The development and application of MR technologies come with various challenges, particularly when it comes to their utilization in the field of art design. One of the primary concerns is the presence of hardware limitations that affect MR functionality, such as sensor tracking and the visual angle of Head Mounted Display (HMD) devices. These limitations can hinder the seamless integration and performance of MR experiences [17]. Cost is another significant obstacle in the adoption of MR technology, as it can be expensive. This financial barrier may restrict smaller companies or organizations from embracing MR due to the requirement for specialized hardware andsoftware that may not align with existing systems or infrastructure. Moreover, the introduction of MR necessitates a new approach to interacting with technology, which may be unfamiliar or uncomfortable for some users. This raises usability concerns and may require additional training or support.

However, there are various challenges thatmust be addressed before the full realization of MR in these domains. One of the foremost challenges pertains to the creation of realistic and immersive MR environments. This necessitates significant advancements in computer graphics, 3D modeling,

Issues surrounding data privacy and intellectual property emerge with the use of MR, highlighting the need for appropriate safeguards and regulations. There are also concerns regarding the potential adverse effects of MR on users' physical and mental health, such as eyestrain, motion

sickness, and altered perception. Additionally, the limited availability of MR content could hinder its overall appeal to users, limiting its widespread adoption. Furthermore, the level of immersion and interactivity achievable in MR is currently constrained by the early stages of its development. As a result, there are still advancements to be made to fully realize the potential of MR experiences. The transformative nature of MR raises bothpositive and negative implications for society and culture, emphasizing the need for careful consideration and responsible implementation. In educational settings, utilizing MR for teaching and monitoring student attention can pose challenges for lecturers. Keeping track of students and managing software tools simultaneously can be initially challenging, leading to increased workload and potential difficulties in effectively conveying information. To address this, it is suggested to have technical support available or involve experienced students as tutors and facilitators to bridge the gap between technology, students, and lecturers [7].

9. THE FUTURE OF MIXED REALITY (MR)

As technology advances and visionaries explore novel methods of blending the virtual and physical realms, the potential of mixed reality becomes increasingly captivating. Immersive tools and devices that facilitate holographic content management are swiftly gaining prominence. While a fully realized mixed reality, experience is still in the works, we are actively seeking optimal approaches to seamlessly integrate digital content into our familiar world. The pace of innovation is surprisingly rapid, surpassing the expectations of many. We are swiftly approaching a point where mixed reality transcends the realm of science fiction and transforms into a tangible possibility. Similar to other components of the extended reality (XR) landscape, the investment in mixed reality has been accelerated by the impact of the pandemic and the growing demand for immersive virtual experiences. The advent of new technologies in this realm will only further enhance our capabilities and possibilities with mixed reality moving forward.

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To illustrate, companies are already harnessing solutions like 5G to diminish latency and enhance the swift transmission of data. The integration of artificial intelligence (AI) holds significant potential in developing MR tools capable of comprehending connections between real and

virtual content. Moreover, with the increasing availability of technology for creating lightweight and powerful smart glasses, coupled with the emergence of new and enhanced software in the MR landscape, we may witness a new mixed reality future sooner than anticipated. Notably, Forrester Research predicts that by 2025, over 14 million workers in the US will be utilizing smart glasses. As businesses strive for a future enriched by extended reality, the opportunities within the realm of MR will continue to expand. However, there is still untapped potential for enhancing the quality and editing of MR content [7]. Predicting the exact trajectory of mixed reality (MR) technology is challenging, but it is highly likely that MR will continue to evolve and progressively integrate into our daily lives. Several potential developments in MR include interacting with and controlling smart devices in our homes and workplaces, creating more immersive and realistic training simulations across a wide range of industries, widespread adoption in the healthcare sector for patient treatment, rehabilitation, and medical training, facilitating communication and collaboration among geographically dispersed team members to enhance remote work support. Furthermore, MR could find greater utilization in the entertainment industry, enabling more immersive gaming and entertainment experiences. In the retail industry, MR could increase adoption by enhancing the shopping experience and allowing customers to visualize products in their own space before making a purchase. Additionally, MR holds potential for new and innovative applications in industries such as construction, military and defense, and tourism and travel. As such, MR is poised to revolutionize various sectors with its transformative capabilities.

10. NOVELTY OF MIXED REALITY (MR)

The novelty of Mixed reality (MR) lies in its potential to transform the way we interact with the world. While challenges exist, the opportunities offered by MR are too significant to be ignored. As technology continues to advance and the ecosystem matures, the path ahead for MR is one of continuous innovation and exploration, ultimately shaping a new era of human experience. MR represents a paradigm shift in human-computer interaction, allowing users to seamlessly interact with both physical and digital environments. This paper delves into the novelty inherent in MR technology, highlighting its potential to revolutionize industries and human experiences. It

also addresses the challenges that need to be tackled for MR to reach its full potential. In terms of the opportunities, it can enhance user experiences. Besides that, it focusing in Training and Education, Entertainment and Gaming, Collaborative Workspaces and Architectural Visualization aswell.

11. CONCLUSION

The future of Mixed Reality (MR) is filled with immense potential, poised to bring about significant advancements and transformative experiences across various fields. However, before MR can be fully realized, several significant challenges must be addressed. The design of future MR systems should prioritize interface automation to provide users with adaptability and a seamless experience [2]. The potential benefits of MR in areas like education and entertainment make it a technology worth investing in for the future of ICT. It is essential to explore new ways of harnessing MR and other upcoming developments for teaching and learning. This could lead to transformative changes in classroom designs, potentially creating holographic-filled spaces and offering instructional designers a whole new range of tools to present captivating student experiences. Online learning could transcend its current limitations, as MR bridges the gap between theory and practice, thereby enhancing motivation and learning [18]. As technology

continues to evolve, MR devices areexpected to become more compact, lightweight, and comfortable, ensuring a seamless and immersive user experience. Advancements in display technologies, including high-resolution and wide field-of-view displays, will contribute to more realistic and engaging MR encounters. The integration of MR into our daily lives holds the potential for significant impact. Imagine the incorporation of MR technology into everyday objects and environments, such as smart glasses or contact lenses that overlay digital information onto the real world. This integration has the power to revolutionize our interactions with the surrounding environment, making routine tasks more efficient and boosting productivity. In summary, the future of MR is promising, but it requires overcoming challenges and embracing advancements to unlock its full potential. With careful consideration and innovative applications, MR can reshape the ICT landscape and enrich various aspects of our lives.

MR has the capacity to revolutionize remote collaboration by enabling virtual meetings in shared immersive spaces. Regardless of their physical locations, users can interact and collaborate, leading to increased productivity and minimized travel expenses. Real-time sharing of virtual objects and annotations enhances communication and stimulates innovation. In the field of education and training, MR holds immense potential. Immersive simulations and virtual environments offer hands-on training experiences in domains like medicine, engineering, and aviation. Students can learn and practice in realistic scenarios, resulting in improved skills and better retention of knowledge. The entertainment and gaming industries will continue to be transformed by MR. By integrating virtual elements into the real world, gaming experiences become immersive, and storytelling becomes interactive. Users can engage with virtual characters and objects in their physical environment, blurring the boundaries between fantasy and reality. In industrial sectors like manufacturing, architecture, and construction, MR can revolutionize processes. Designers and engineers can visualize and manipulate 3D models in real-time, enhancing the design phase and reducing errors. Maintenance and repair tasks can be streamlined by overlaying real-time instructions and information on physical equipment. The potential of MR in healthcare is significant. Surgeons can benefit from real-time overlays of patient data during operations, improving precision and reducing the likelihood of errors. Telemedicine can also be facilitated through MR, enabling remote specialists to virtually examine and guide healthcare providers in real-time. Social interactions can be transformed by MR through the overlay of digital information and virtual elements onto real-world social gatherings. Users can share experiences, play games, and interact with virtual avatars, fostering social connectivity and enabling new forms of digital communication.

In the future, the integration of virtual and physical realities through MR is expected to bring about advancements in productivity, entertainment, education, healthcare, and other areas of our lives. As technology continues to progress and more applications are developed, MR is likely to become an integral part of our daily experiences. Learners have found the use of MR in remote teaching to be beneficial, as it provides a realistic experience and improves understanding compared to traditional teaching methods. Teachers also acknowledge the effectiveness of MR in conveying knowledge [7]. MR has become a game-changer for various industries, offering unique experiences that are increasingly essential. Companies that fail to incorporate AR, VR, and MR technologies risk being left behind. While we are still in the early stages of exploring the full potential of MR due to its complex nature, the possibilities are virtuallylimitless [19, 20]. The future of MR appears promising, with the potential to significantly impact and enhance numerous aspects of our lives.

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