RESEARCH ARTICLE OPEN ACCESS

Augmented Reality and Holography: Redefining the Way of Human-Computer Interaction

R Bhargav[1], Mallesh C N[2], Hitesh K R[3], Vinisha S[4]

[1](Department of Computer Science Engineering, Presidency University, Bangalore-560064
Email: rbhargav2003@gmail.com)

[2](Department of Computer Science Engineering, Presidency University, Bangalore-560064
Email: cnmallesh500@gmail.com)

[3](Department of Computer Science Engineering, Presidency University, Bangalore-560064
Email: kanagalahitesh@gmail.com)

[4](Department of Computer Science Engineering, Presidency University, Bangalore-560064
Email: vinishas524@gmail.com)

--************************----------------------------------

Abstract:

This research article deals with the comparative analysis of Augmented Reality (AR) and Holography in Human-Computer Interaction (HCI). In a world of rapidly advancing technology, the need for more immersive and intuitive interfaces has grown exponentially. Human-computer interaction (HCI) deals with the design and use of computer technologies which are used as a medium of interaction between humans and computers. Augmented Reality (AR) is an interactive technology that combines real-world and computer-generated content while Holography is a photographic technique that records the light scattered from an object and then presents it in a way that appears in three-dimensional, both holding a significant impact on Human-computer Interaction (HCI). We examine the foundational principles, technological progress, and applications of Augmented Reality (AR) and Holography, highlighting each's strengths and limitations. Through numerous applications spanning education, healthcare, gaming, and industry, we demonstrate the impact of Augmented Reality (AR) and Holography on Human-Computer Interaction (HCI). The objective is focused on their convergence showcasing how this integration can revolutionize human interaction with computers. In conclusion, the fusion of Augmented Reality (AR) and Holography promises a new era of visual computing interfaces bridging the gap between the digital and physical worlds.

Keywords — **Augmented Reality, Holography, Human-Computer Interaction, HoloAR.**

--************************----------------------------------

I. INTRODUCTION

Humans interact with computers in many possible ways and the interface through which they interact plays a vital role in simplifying the interaction. Desktop applications, internet browsers, and handheld computers make use of graphical user interface (GUI) as a medium of interaction between user and computer. The growth in Human–Computer Interaction (HCI) field has led to an increase in the quality of interaction which in turn resulted in many new areas of research. Two such cutting-edge technologies, Augmented Reality (AR) and Holography have had a significant impact in redefining the way of Human-Computer Interaction.

Augmented Reality (AR) refers to a technology that combines digital information such as images, text, or 3D objects onto the real-world environment in real-time. Users view the visual representation of objects through devices like smartphones, AR glasses, or a head-mounted display. The advancements in Augmented Reality (AR) provided many industries including education, health care, construction, and manufacturing a huge boost in terms of productivity and efficiency. Augmented Reality (AR) provides spatial interaction, contextual information overlay on physical surroundings, and immersive experience to enhance Human-Computer Interaction (HCI).

Holography is a photographic technique that records the light scattered from an object and then presents it in a way that appears three-dimensional. Users do not require any device to view the holographic image or projection. The object is represented as a three-dimensional image with the help of waves present in the atmosphere. The advancements in Holographic technologies may improve the efficiency of existing products and services in sectors such as architecture, 3D modeling, mechatronics, robotics, and healthcare. Holography provides telepresence, advanced data visualization, and realistic 3D representation to enhance Human-Computer Interaction (HCI).

Augmented Reality (AR) and Holography separately have proved their significance in Human-Computer Interaction but their convergence can be a potential leap in the realm of user experience and Human-Computer Interaction. There are several theories and models that integrate Augmented Reality (AR) and Holography which not only bridges the gap between humans and computing machines but also opens the door for non-wearable and highly interactive methods enhancing the user experience.

II. METHODOLOGY

The motive to follow this methodology defines the approach to perform research on the integration of Augmented Reality (AR) and holographic technology with their implications across various domains. The goal of this research is to provide meaningful insights by conducting a comparative analysis between Augmented Reality (AR) and Holography in the evolving field of Human-Computer Interaction. Augmented Reality (AR) technology overlays digital content onto the real world using devices such as smartphones or AR glasses. In the case of wearable devices, users can wear AR glasses with specialized lenses or a holographic visor. These glasses create a display that allows users to see the world around them and holographic content simultaneously. Holographic lenses which are a component of these devices try to optimize the clarity of images. Augmented Reality can enhance this experience further by providing real-world data, such as location-based information or real-time environmental data that can be overlaid onto the holographic scene which enhances the productivity of interaction.

III. MATERIALS AND METRICS

This section will discuss the hardware software and user requirements of Augmented Reality (AR) and Holographic technology which is crucial in understanding the implementation of these two immersive Technologies in a real-time environment. Exploring the components of Augmented Reality and Holographic systems becomes important to find out the future implications and development in Human-Computer Interaction.

A. *Augmented Reality*

1) *Hardware Requirements used in AR:*

The hardware used in augmented reality (AR) technology can be divided mainly into two main categories:

Display: The display is the device that presents the AR content to the user which is classified as:

- Head Mounted Displays (HMD): HMDare worn on the head to experience enhanced AR experience.
- AR Glasses: similar to regular glasses, they have a built-in display that allows the user to see AR content that is overlaid on the surroundings.
- Devices: AR output can also be displayed on devices but the disadvantages lie in experience as it is not as immersive as a headset can be.

Sensors: Sensors are used to track the user's movement and position in the real world, wearing HMD.

- Accelerometer: measures the change of speed of the device.
- Gyroscope: measures the rotation of the headset.
- Camera: The main sensor used to capture images of the surroundings and to track the user's movement and position.

Computing Resources: used to render and overlay the AR content and track the user's movement.

- Rendering**:** Process of generating an image from a digital model by the processor
- Tracking: Tracking is the process of estimating the position and orientation of the user's device in surrounding space to accurately point the visual content.
- Graphics processing unit (GPU): Used to accelerate the rendering of graphics and AR content.

1. Software Requirements Used in AR:

The main core of AR technology lies in the exceptional software that is capable of generating content. The software requirements are:

- **Operating system**: When comes to AR-based devices, the content is usually displayed on devices run on mobile operating systems such as IOS and Android
- **AR development platform**: A software suite that provides the tools and resources needed to develop AR content and apps. This also includes the software development kit including the simulation platform such as Unity, Unreal Engine, and ARKit/ARCore.
- **AR runtime**: A component in the toolkit that allows AR applications to display AR content on the user's device, and is provided by hardware manufacturers such as Apple or Google. Examples include ARKit (Apple) and ARCore (Android).
- **Image recognition software**: This software is used to identify and track objects in the users' surroundings. Often called Computer Vision, plays a vital role in the visual arena to find the point of overlay execution of digital content onto real-world objects.
- **Spatial tracking software:** This software is used to track the position and orientation of the user's device in space as it is essential for AR apps requiring accurate positioning of AR content.

2) User requirements:

The requirements adhered to by the user are considered in developing and redefining AR technology. Some requirements are:

- **3D display and Quality Result**: Users expect the device to display the content in 3D format which allows them to interact with the objects as if they were real.
- **Real-time tracking:** Users expect the device to track the position and orientation of the AR objects in real-time as and when they move thus allowing the AR content to appear as fixed in the real world, even as the user moves around.
- **Realistic image**: Users expect the AR objects to look as realistic as possible while expecting a comfortable viewing area and ease of Usage in terms of device.

3) AR System:

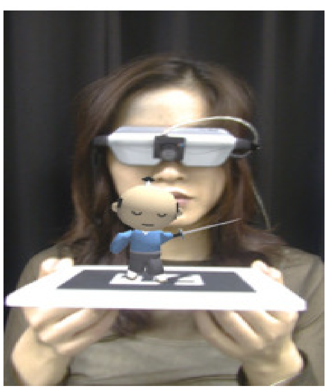
A typical AR system consists of three components: a geospatial datum for the virtual object, a surface to project virtual elements, and an image processing unit.

- **Geospatial Datum**: AR relies on accurate geospatial data for aligning virtual objects with the real world. This typically involves GPS data, digital maps, and location-based services (LBS) to establish the user's position and orientation.[1]

- **Surface for Projection**: Virtual elements in AR require a surface upon which they can be projected or overlaid. This surface could be any physical object or the environment itself. In some cases, fiducial markers or markers are used to identify suitable surfaces.
- **Image Processing Unit**: The image processing unit is responsible for tracking the user's environment, recognizing objects, and rendering digital content in real-time. It involves computer vision algorithms for object recognition, tracking, and spatial mapping.(1)

4) AR Devices:

AR systems witnessed a drastic and progressive change from dedicated devices to more accessible platforms. Early AR systems required specialized hardware such as smart glasses (e.g., Microsoft HoloLens, Google Glass), or fixed devices like PCs with webcams. These systems offered limited applications and were primarily used for research and development. This has led to a number of improvements in QoE (quality of experience), output, and usage. Apps based on AR are now available for a wide range of purposes including gaming, education, marketing, healthcare, navigation, and maintenance.



ARKIT (2)

B. Hologram

1) Hardware:

Key hardware components of the Hologram device include (3) (4):

- The hologram device features a 3D display screen that provides a resolution of 1268 x 720 pixels per eye giving users an experience, with a 16:9 aspect ratio. The screen operates at a rate of 60 Hz and is enhanced by specialized holographic lenses to optimize image clarity.
- To capture the surroundings and detect light the device is equipped with a high-resolution depth camera that has a resolution of 1208 x 1208. It also includes four cameras with sensors for sensing and detecting ambient light.
- User interaction is made easy through integrated measurement units such as an accelerometer, gyroscope, and magnetometer. These allow users to seamlessly interact with the hologram device using gestures and head movements.
- For communication the device comes with integrated speakers and a sophisticated array of four microphones enabling two-way communication.

- At the core of the hologram device is its Holographic Processing Unit (HPU) which can perform one trillion calculations per second. This processing capability is supported by a random access memory (RAM) capacity of 2 gigabytes (GB).
- In terms of storage space, the device offers flash storage of 64 GB. It also provides connectivity options including support, for Wi-Fi (IEEE 802.11ac). Bluetooth (4.1 Low Energy).The battery life of the device is really impressive. It can last for, up to three

hours of use on a charge and it has a standby time of around two weeks.[(3) (4)]

2) *Software:*

The hologram device operates using a specialized software platform tailored for holographic experiences. This software platform is seamlessly integrated into the device's native operating system, providing access to a curetted repository of holographic applications. Users can effortlessly download and install applications specific to the hologram device from the dedicated holographic application store. [(3) (4)]
Gestures play a role in facilitating interaction within the augmented reality (AR) environment of the HoloLens. There are three gestures incorporated:

- **Bloom Gesture**: Users initiate this gesture by raising an open palm with closely positioned fingertips and then gracefully spreading their fingers outward. The bloom gesture serves as an elegant means to launch applications and gracefully close them.
- **Air Tap Gesture (Tap and release)**: Executed by raising and flexing the index finger in a pinch-like fashion, similar to tapping and releasing, with the dorsal aspect of the user's hand facing them. The air tap gesture is employed for selecting various operations or options within the holographic environment.
- **Tap and Hold Gesture**: Users engage the tap and hold gesture to manipulate selected objects within the holographic space. This gesture involves raising the index finger toward the thumb while simultaneously bringing the pressed fingers together. Manipulation typically occurs within the three-dimensional space, involving both upward and downward movements.

These gestures are designed to provide users with a seamless and immersive means of interacting with holographic content and objects. [(3) (4)]

3) *Quality-of-service (QoS):*

These are the hardware components designed to assess the QoS of the device, specifically focusing on its performance and accuracy. [(5)]

- **Sensors**: The essential parts for tracking the user's environment and enabling augmented reality experiences. The devices are equipped with various sensors, including cameras, accelerometers, gyroscopes, and depth sensors.
- **Display**: A see-through display system that overlays holographic images onto the user's real-world view.
- **Audio Components**: The device includes speakers and microphones for immersive audio experiences and voice commands.

4) *Quality-of-Experience (QoE):*

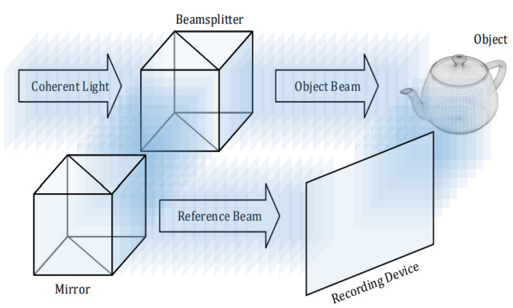
This Model is not a hardware component but it is used to evaluate the overall user experience and usability of HoloLens and similar AR devices. [(5)]

- **User Interaction**: It provides the responsiveness of the device to the user's gestures and voice commands and how users interact with holographic objects.
- **Visual Quality**: Checking the clarity, resolution, and stability of holographic images and verifying the level it is integrated with the real-world environment.
- **Comfort and Ergonomics**: Make sure that it is comfortable and convenient for users to wear and use the AR glasses for extended periods without any physical harm.

5) *Fuzzy Inference System (FIS):*

This system is a Software-based model. It is a mathematical model used to quantitatively evaluate the Quality of Experience (QoE) of AR Smart Glasses (ARSGs) like HoloLens. (5)

- **Input Parameters**: This takes input parameters related to the AR experience, which may include data from the functional components, user interaction data, visual quality metrics, and comfort assessments.
- **Fuzzy Logic**: It allows the system for the modeling of uncertain data, which is common in user experience evaluations.
- **Inference Rules**: These sets of rules are used to process the input data and make quantitative assessments of the QoE.
- **Output**: The model generates an output that quantifies the overall user experience, usually on a numerical value.



A holographic imaging system for hologram recording. (4)

IV. THEORETICAL FRAMEWORK

The theoretical framework aims at presenting the current technological landscape of both the technology for a better understanding of the progress as well as the possibility of combining the two for better Human-Computer Interaction or UX.

Augmented reality (AR) and holography are both technologies that overlay digital information onto the real world. However, there are some key differences between the two. AR overlays digital information onto the real world while holography creates three-dimensional images that appear to float in mid-air. AR is displayed on a device such as a smartphone or tablet, while holography is on specialized devices such as heads-up displays or smart glasses.

In the exploration of the technologies and their integration, we mention the theories that support this synergy. Theories of attention, perception, spatial awareness, navigation, social presence, and interaction provide the theoretical backdrop. We also consider the Technology Acceptance Model (TAM) and Presence Theory.

A. *Theories and Models*

1) **Theory of Attention and Perception**: It explains how people selectively focus on specific information and interpret it in their perceptual processes with regard to technology. (6)

   AR: AR leverages this theory to seamlessly blend digital information with the user's real-world view as it focuses on directing user attention to relevant digital content within the physical environment.

   Holography: Holography also engages theories of attention and perception but offers a more immersive experience as it creates 3D holograms that users can interact with directly, captivating attention and perception through lifelike visualizations.

2) **Theory of Spatial Awareness and Navigation:** It explains how people understand and move through physical spaces, including how they use environmental cues, such as digital content. (7)

   AR: AR enhances spatial awareness by providing real-time contextual information overlaid onto the physical environment as it supports navigation by offering visual cues and directions.

   Holography: Holography provides spatial awareness by creating 3D holograms that occupy physical space.

3) **Theory of Social Presence and Interaction**: It examines how people feel connected to others in online environments and how they interact socially in these contexts. (8) AR: AR promotes social presence by allowing users to interact with digital elements while maintaining awareness of their physical surroundings.
   Holography: Holography can enhance social presence when users engage with shared holographic content.
4) **Technology Acceptance Model (TAM):** This model assesses users' willingness to accept and use new technology based on perceived usefulness and ease of use. (9)
   AR: AR applications often align well with TAM as they provide practical, easy-to-use solutions that enhance user tasks and experiences.
   Holography: Holography, while captivating, may face higher initial resistance due to its complexity and cost, potentially affecting its TAM scores.
5) **Presence Theory:** This is the main theory that examines the sensation of being present in a mediated environment, often associated with immersive experiences, such as virtual reality or holography. (10)
   AR: AR contributes to presence theory by enhancing the user's sense of being within a mediated environment, thanks to its contextual overlays and interactivity.
   Holography: Holography provides a sense of presence by creating tangible 3D holograms, making users feel as if the objects exist in their space.

B. *Contemporary Landscape of these technologies*

1) **Fighter Jets HUD**: Currently Pilots Heads-up-Display employs AR technology due to their ability to provide real time data overlay and immediate access to critical data. As they are designed for mission-critical tasks, using Hologram in that High-Stress environment is not affordable as the project could match the milliseconds data relay at a speed jets fly. The integration of AR and holography in HUDs could provide pilots with a comprehensive view of critical data, enhancing decision-making in high-stress situations.
2) **Consumer Wearables:** Facebook Ray-ban stories and Google AR Glasses (discontinued) leverage AR technology for projection and capturing the visual overlays through the camera. The potential to use the integration may include incorporating the sensors ranging from motion-sensing and physical-mapping sensors into the wearable which could drive negative TAM to the products.
3) **Microsoft HoloLens:** A Mixed Reality headset that combines AR and Holographic elements. This provides a glance to the future of integrating both the technologies to process the interactions in hindrance-free data overlay and it also provides a functional way to carry holograms all around the time. (11)
4) **Hologram Table:** a large, flat surface with a built-in projection system. The table projects light through a transparent film that interacts with four sets of tracked glasses. (insert figure of hologram table) Hologram tables use holographic technology to create 3D visualizations. Integrating AR with

hologram tables could enhance their interactivity by providing real-time contextual information. This makes the product market-ready and viable, especially in educational and design contexts where enhanced visualization is valuable. One prominent reason why integration can be found invaluable is the ability to remove the Holo table OS which acts as the sole pillar of projection and rendering. [12]

C. Key findings

The In-depth analysis of both technologies with respect to the aforementioned theories combined with insights from the practical implementations provides a few key findings that could pave the way to prove how the integration of AR and holography can transcend the limitations of each technology in isolation enhancing user experiences in ways never before possible.

Theories Outcome:

Holography, a as standalone, may not offer navigation assistance like AR-based devices also it may not support real-time social interaction as seamlessly as AR. In contrast, AR lacks the ability to generate more realistic or life-like animation and images, which hologram excels in.

Situational considerations also come into play wherein AR may be preferable when real-time interaction with the physical world is essential, such as gaming and Holography may be more suitable for applications like medical imaging, architectural visualization, or artistic installations that require immersive 3D visuals.

Hologram processing is the primary bottleneck and contributes to more than 50% of energy consumption in battery-operated augmented reality (AR) headsets. **Pokémon GO** (launched in July 2016), had a cumulative download of over 1 Billion. More AR capable mobile devices penetrating the market made AR applications pervasive and made the virtual world easily accessible for users on the tip of their fingers. However, even state-of-the-art mobile devices with high bandwidth cannot meet the heavy computing and real-time demands of AR applications, leading to very low quality of service (QoS).

D. Integration of AR and Hologram

In practice, integrating both technologies strategically can provide a versatile solution that adapts to various situations, offering the best of both worlds for an optimal UX. Thus, from the analysis of theories and progress, this brings into a stalemate that integrating both AR and Hologram could be a game-changer for HCI as it can provide an exceptional user experience (UX). [14]

1) **HoloAR:**

With the rapid development of computer technology, holograms can now be calculated by algorithms. [15] Thus, given the analysis of each technology, a study presented by The Pennsylvania State University, proposes a novel framework for holographic processing in AR applications, **HoloAR** [13] which aims to improve both performance and energy consumption of hologram processing while maintaining an acceptable video quality.

HoloAR utilizes the existing viewing-window based technique to skip the hologram computations for the objects which are outside of the current viewing window, in a "just-in-time" fashion. HoloAR employs the Inter-Holo scheme to take advantage of the region of focus by analyzing the current eye-tracking inputs and sparsely computing the objects outside the Region of Focus.

2) **"4-View" Display technology:**

One alternative for the HoloAR framework has been incorporated into a device out in the market, **Red Hydrogen One,** often referred to as the "holographic phone" or "hologram phone." The device featured a unique display technology called "4-View," [16] which allowed users to view 3D content and holographic images and videos.

With "4-View" technology, the display creates the illusion of depth and 3D by showing slightly different images from four different angles simultaneously, namely, Front, Right, left, and Top. The major variance between these 3D and 4-View Display lies in the depth perception. 3D technology creates the illusion of depth making objects on a screen appear to have varying distances from the viewer. This technology works by showing slightly different images to each eye, which tricks the brain into thinking that the images are three-dimensional. Instead of relying solely on the separation of images for depth perception, "4-View" creates depth by showing different angles of the same scene, which your brain interprets as three-dimensional.

Thereupon, highlighted by HoloAR's efficient holographic processing and the "4-View" display technology's immersive 3D experiences, these innovations represent the forefront of HCI evolution. The seamless blend of digital overlays and lifelike holograms offers unparalleled user experiences, setting the stage for a dynamic and immersive digital realm.

V. RESULTS

3D holographic projection technology as a prevailing visual high-tech has been very popular in recent years. AR and Holographic Technology have a thin line between the real world and the digital world. The combination of holograms and AR allows for complex data, models, and information to be visualized in three dimensions within a real-world context. This is particularly valuable in fields like medicine, engineering, and education, where precise 3D visualization is essential. Combining holography with augmented reality (AR) presents a compelling solution to strong arm the limitations of each technology.

The Achilles heel of holographic technology has been its limited field of view, a challenge that can be adeptly addressed when integrated with AR. By selectively displaying holographic elements within the AR headset's field of view, the limited viewing angle can be expanded, providing its users the ability to interact with holograms along with the immersive experience of the digital content. AR often gets sidelined due to the lack of depth perception, as it mainly relies on 2D screen displays. Integrating holography into AR improves the user experience by implementing depth effects, and rendering digital objects in a more realistic and 3D manner. Holography is well-known for high-end hardware and complex setups such as specialized equipment such as lasers, beam splitters, and sensors which is considered as a reason for its limited adoption.

However, by fusing holography with AR headsets or devices, accessibility can be democratized and made affordable for the consumer market. This could expose the usage and applications of holography to a wider market, making it more feasible and economically viable. The realism of AR experiences can sometimes hinder the experience in terms of object placement and interaction with the environment. Holography, with its ability to create realistic 3D objects, can enhance this limitation of AR. Also, holography often requires an optimum environment with appropriate lighting conditions. AR, on the other hand, adapts to a limited environment. Merging these technologies could promise holographic AR experiences with much more practicality in the real world.

AR, given the current technological outcome, fits in the size of the display screen, which limits the contents it can supposedly convey. Here, Hologram, using its devices can expand the display size, to help to accommodate its potential contents within AR applications. Moreover, AR devices are limited to touch screens or gesture-based interactions, which may not always feel immersive. The integration of holography introduces the potential for more natural and highly interactive interactions e.g., voice commands, or gesture manipulation of hologram objects, etc. The static nature of holographic displays can also be overcome through integration. By coupling holography with AR headsets, users gain the mobility to navigate and interact with holograms in a variety of physical environments. Even though this merger helps to address multiple disadvantages, it is important to consider the technical challenges which can be

narrowed down to the development of lightweight and cost-effective hardware.
While the forerunner of this field, Microsoft Hololens and Magic Leap One aims to capture it as a whole, the acceptance of outcome technology by users will be a major factor in determining the success of integrated output. As the relentless march of technology continues, the merging of holography and AR is tailored to redefine how we engage and interact with the digital realm, offering a glimpse into the future of immersive and dynamic Human-Computer Interaction (HCI).

VI. CONCLUSIONS

In the era of technology where Human-Computer Interaction is evolving at an unprecedented pace, "Augmented Reality" and "Holography" are the two major immersive and intuitive technologies that enhance our interaction with computers and digital content. This research article examines the fundamental concepts, technological advancements, and current applications of Augmented Reality (AR) and Holography describing their individual strengths and limitations. However, it is the seamless integration of these two technologies that amplifies their transformative potential for redefining the way of Human-Computer Interaction. One of the most significant advantages of this integration is the facilitation of natural and intuitive interactions. Users can manipulate digital objects and information in 3-dimensional space using gestures, voice commands, and physical movements. Several such technologies that are still under development that integrate AR and Holography are "HoloAR" and "4 view display" technology. The potential applications of integrated AR and Holography are vast and span diverse across various domains. In education, students can explore historical events through interactive AR-enhanced textbooks or dissect holographic organisms for biology classes. In healthcare, surgeons can rehearse complex procedures on lifelike holographic models before performing an operation. Industrial workers can receive real-time guidance through AR overlays while interacting with 3D holographic schematics for complex machinery maintenance. Nevertheless, the journey ahead also presents challenges notably in terms of privacy, security, and ethical considerations.

In summary, the integration of Augmented Reality and Holography re-defines the way we interact with computers and digital content, ushering in a new era of Human-Computer Interaction (HCI). This fusion of technologies empowers us to build interfaces that are not only more immersive and intuitive but also more closely aligned with the human experience. By continuing to explore, innovate, and responsibly deploy these integrated technologies, we can create a future where technology augments our capabilities and enhances our connection to the digital world ultimately serving the best interests of humanity in an increasingly digital age.

REFERENCES

(1) AUGMENTED REALITY MARKETING: A SYSTEMATIC LITERATURE REVIEW AND AN AGENDA FOR FUTURE INQUIRY ZHAO DU*, JUN LIU AND TIANJIAO WANG BUSINESS SCHOOL OF SPORT, BEIJING SPORT UNIVERSITY, BEIJING, CHINA
(2) A Survey of Augmented Reality Mark Billinghurst, Adrian Clark, and Gun Lee The Human Interface Technology Laboratory New Zealand University of Canterbury Christchurch, New Zealand {mark.billinghurst, adrian.clark, gun.lee}@hitlabnz.org
(3) Augmented Reality Technology Using Microsoft HoloLens in Anatomic Pathology Matthew Hanna, Ishtiaque Ahmed, Jeffrey Nine, Shyam Prajapati, Liron Pantanowitz.
(4) Hardware Implementations of Computer-Generated Holography: A Review Youchao Wanga, Daoming Dong, Peter J. Christopher, Andrew Kadis, Ralf Mouthaan, Fan Yang, Timothy D. Wilkinson, University of Cambridge, Centre for Molecular Materials.
(5) Towards a QoE Model to Evaluate Holographic Augmented Reality Devices A HoloLens Case Study Longyu Zhang, University of Ottawa, Haiwei Dong, University of Ottawa, Abdulmotaleb El Saddik, University of Otta.
(6) Rensink, Ronald. (2013). Perception and Attention. 10.1093/oxfordhb/9780195376746.013.0007. (https://www.researchgate.net/publication/236170002_Perception_and_Attention)
(7) McNamara, Timothy. (2017). Spatial Memory and Navigation. 10.1016/B978-0-12-809324-5.21043-2. (https://www.researchgate.net/publication/313585447_Spatial_Memory_and_Navigation)
(8) Lowenthal, Patrick. (2009). Social Presence. 10.4018/978-1-60566-198-8.ch280. https://www.researchgate.net/publication/265375995_Social_Presence)
(9) Rauniar, Rupak&Rawski, Greg &Jei, Yang & Johnson, Ben. (2014). Technology acceptance model (TAM) and social media usage: An empirical study on Facebook.Journal of Enterprise Information

Management. 27. 10.1108/JEIM-04-2012-0011. (https://www.researchgate.net/publication/263555990_Technology_acceptance_model_TAM_and_social_media_usage_An_empirical_study_on_Facebook)
(10) Lombard, Matthew & Lee, SongyiGrace & Sun, Weimei& Yang, Hocheol. (2017). Presence Theory. 10.1002/9781118783764.wbieme0087. (https://www.researchgate.net/publication/326398872_Presence_Theory
(11) Anthony Pires, Shelley Midthun (2020) (https://static1.squarespace.com/static/5492276ce4b0df519b06a6ce/t/58ea48b617bffc10a35e5339/1494971255179/OSB+CCC+HoloLens+Academic+Grant+Whitepaper.pdf)
(12) Axiom Hologram Tables (https://axiomholographics.com/devices/hologram-table/)
(13) The Pennsylvania State University (https://par.nsf.gov/servlets/purl/10328208)
(14) (https://scholarspace.manoa.hawaii.edu/server/api/core/bitstreams/030a795b-1dc9-4967-8b20-e2db30010762/content)
(15) A. Kozma and D. L. Kelly, "Spatial filtering for detection of signals submerged in noise," Appl.Opt. 4, 387–392 (1965).
(16) (https://www.theverge.com/2018/10/29/18027782/red-hydrogen-one-review-all-hype)
(17) https://visartech.medium.com/microsoft-hololens-explained-how-it-works-and-which-business-industries-may-benefit-80f535bda4c3
(18) https://www.cnet.com/reviews/magic-leap-one-preview/