

Wearable Technologies in Gaming

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Abstract: Wearable technology has surged in popularity, revolutionizing multiple sectors and reshaping our daily lives. With the rise of AR, VR, and fitness-based games, wearables are transforming how we engage with games. Wearable tech for gamers refers to electronic devices designed to be worn on the body, enhancing the gaming experience by providing immersive, interactive, and personalized features. It includes devices like VR and AR headsets, smart glasses, haptic suits, and gloves that provide immersive and interactive experiences. These devices make players feel more present in the game world. People who enjoy playing video games now have access to a range of highly sophisticated, wearable devices that enhance the overall gaming experience and make it far more immersive and engaging. This paper explores the growing usage of wearables in gaming.

Keywords: Wearables, Wearable Devices, Wearable Technologies, Immersive Technologies, Gaming

I. INTRODUCTION

Wearable devices are electronics and computers incorporated into clothing and other accessories which can be worn comfortably on the body. These devices have become a mainstay in everyday life. They include a wide variety of devices such as smart-watches, smart glasses, activity trackers, head-mounted displays, contact lenses, smart garments, smart jewelry, headbands, bracelets, etc.[1]. Wearable technology is rapidly gaining traction and reshaping various industries, and the gaming sector is no exception. From smartwatches to VR headsets, wearable devices have become an integral part of our lives, offering not only convenience but also gaming capabilities. Wearable gaming offers a hands-free and interactive gaming experience where users can seamlessly engage with digital content while fully immersed in their surroundings.

Gaming and technology go hand-in-hand when it comes to developing the latest trends and making gaming a better experience for customers. Wearable gaming refers to integrating gaming features and experiences into wearable technologies. Wearable technology is any electronic equipment intended to be worn on the user's body. It can come in various shapes and sizes, such as accessories, medical equipment, smartwatches, activity trackers like the Fitbit Charge, smart jewelry, web-enabled eyewear, Bluetooth headsets, and clothing or clothing-related items. The most advanced wearable technology includes holographic computers in virtual reality (VR) headsets, Google Glass, Microsoft's HoloLens, and artificial intelligence (AI) hearing aids. Wearables function uniquely depending on the area they fall under such as health, fitness, sports, education, or entertainment. While the majority of wearables are either worn on the body or are sewn onto clothing, some operate without coming into contact with the wearer. Wearables are revolutionizing how people interact with games with the development of AR, VR, and fitness-based gaming [2].

II. WHAT IS WEARABLE TECHNOLOGY?

A wearable device is any device that is worn comfortably on the body and enables user interaction. It is typically integrated into the clothing or attached to the body of a person to enhance human performance. It often includes smart devices that can be worn on the body or attached to clothes. Wearable devices have been around for centuries. The first one was introduced in the 1660s by the Qing Dynasty. Since then the popularity of wearables has shifted from royalty to the healthcare industry. Wearable computing is a natural evolution of the smartphone technology that has become so ubiquitous and indispensable in education, business, and medicine. We wear wrist watches to know the time. Perhaps the most crucial bit of wearable tech accessible today is Google Glass. There has been a proliferation of wearables from consumer gadgets to medical devices that are approved by the Food and Drug Administration (FDA).

Wearable devices or systems are usually lightweight, miniature electronic or digital devices that are worn by a user, including clothing, watches, glasses, shoes, and similar items. A wearable computer is computer-powered device that is never-sleeping ever-present network-connected electronic system that can be used at anytime and anywhere and does not in any way disturb the user's interaction with the real world. It should be worn, much as eyeglasses or clothing are worn, and interact with the user [3]. It includes all manner of technology that is on or in the body such as fitness trackers, smartwatches, smart clothing, smart rings, smart glasses, wearable mobile sensors, smart jewelry, and smart ECG (electrocardiogram) monitors.

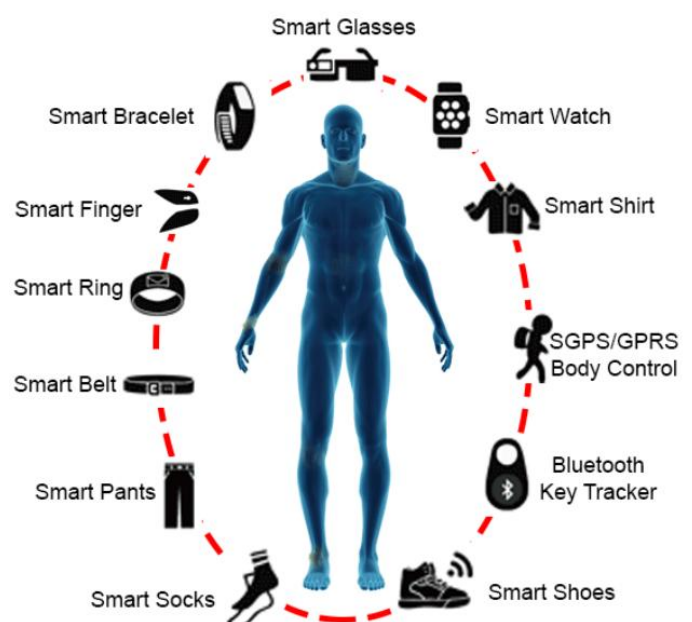


Figure 1: Different types of wearables on human body [5].

Wearables are always ready, unrestrictive, not monopolizing of user attention, observable and controllable by the user, attentive to the environment, useful as a communication tool, and personal devices [4]. Wearables are being used across healthcare, insurance, interactive systems, safety critical settings, wearable cameras, baby and pregnancy monitors, entertainment, fitness and sports, emergency responders, and military. Typical wearable devices are shown in Figure 1 [5]. Due to its wide range of applications, international corporations such as Google, Apple, and Intel are investing heavily on wearable technology research and development [6]. As with any new technology, one must exercise caution when using a wearable device.

A wearable device essentially consists of two different components: wearable and body sensors. It incorporates sensors, memory, solar cells, and batteries. It stays in contact with the body for extended periods of time. Traditional materials for wearables are mostly metals and semiconductors with relatively poor mechanical flexibility. Modern wearable technologies are characterized by body-worn devices, as smart clothing, e-textiles, and accessories [7]. Wearable devices can be used to collect various data to support a series of innovative applications. Today, wearable devices have numerous applications due to their integration with artificial intelligence. Wearable devices can be attached to shoes, eyeglasses, earrings, clothing, gloves, and wrist watches [8].

III. WEARABLE GAMING TECHNOLOGY

The gaming industry has evolved dramatically over the years, and wearable technology is at the forefront of this transformation. From immersive virtual reality (VR) headsets to biometric tracking devices, wearable tech for gamers is redefining how players interact with games and their environments. The impact of wearable technology on game development has been significant, leading to a disruption of traditional approaches. Wearable gaming refers to integrating gaming features and experiences into wearable devices, such as smartwatches, augmented reality (AR) glasses, fitness trackers, and virtual reality (VR) headsets. Unlike traditional gaming setups that involve controllers or keyboards, wearable gaming brings games directly to the user's body, allowing for intuitive and natural interactions.

The journey of wearable technology in gaming began with rudimentary devices like the Nintendo Power Glove in the late 1980s. The technology failed to gain widespread adoption. One of the first examples of wearable technologies was recorded in 1970. In the 2010s, and the gaming industry witnessed a revolution with the introduction of VR headsets, which set the stage for immersive gaming experiences. In recent years, companies like Sony, Microsoft, and Meta are continuously pushing the boundaries, integrating AI and machine learning to create smarter, more responsive devices [9]. The gaming industry has always been at the forefront of technological innovation, constantly pushing boundaries to deliver immersive and engaging experiences. Wearable technology, once a niche concept, has now emerged as a game-changer in this space.

IV. TYPES OF WEARABLE DEVICES

Wearable gaming has ushered in a new era of interactive and immersive experiences, offering various game types that cater to different preferences and interests. Due to this, there are presently many different kinds of wearable technology. Some of these wearables are shown in Figure 2 [10]. The most

common types of wearable technology include the following [11]:



Figure 2: Some wearables [10].

1. *Smart Watches*: These devices offer features like fitness tracking, notifications, messaging, music control, and mobile app integration. Smartwatches and fitness trackers are no longer limited to monitoring health and fitness; they have evolved into gaming accessories as well.
2. *Smart Clothing*: This includes garments and accessories embedded with sensors or conductive threads, enabling functions like tracking biometrics, monitoring posture, or adjusting temperature.
3. *Smart Jewelry*: Fashionable accessories like rings, bracelets, or necklaces that incorporate technology such as fitness tracking, notification alerts, or contactless payment capabilities.
4. *Smart Glasses*: These are glasses, like Google Glass, provide that can overlay digital information onto the real world, allowing for AR gaming experiences. These eyewear devices provide hands-free access to information, notifications, and navigation, displaying a small screen in the wearer's field of vision. These provide a heads-up display for gaming and other applications, allowing for hands-free operation.
5. *Fitness Trackers*: While not always the primary gaming device, smartwatches, and fitness trackers can be used for certain games or as companion devices that provide information, control gameplay, or track fitness-related game progress. These devices monitor metrics such as steps taken, distance traveled, calories burned, and heart rate during physical activities.
6. *Virtual Reality Headsets*: Virtual reality (VR) headsets provide immersive experiences by placing the user in a virtual environment. It is often used for gaming, entertainment, or training purposes. With advancements in display resolution, field of view, and tracking technology, VR headsets now offer more realistic and detailed visuals, making the virtual world feel even more believable. AR overlays digital elements in the real world, creating interactive and engaging gaming experiences.
7. *Augmented Reality Glasses*: Augmented reality (AR) glasses overlay digital information onto the real world, enhancing the user's perception and interaction with their surroundings. They overlay digital content onto the user's view of the physical environment, creating interactive and dynamic gaming experiences. Recent advancements in AR glasses have resulted in improved tracking, better field of view, and enhanced graphics, enabling more seamless and immersive AR gaming experiences.

8. *Biometric Sensors*: Advancements in wearable gaming technology also include the integration of biometric sensors and emotion detection systems. These devices can monitor physiological indicators such as heart rate, skin conductance, and facial expressions to gauge the player's emotional state and tailor the gameplay accordingly. Game developers can use motion sensors and biometric data tracking capabilities to create immersive and interactive gaming experiences.

V. APPLICATIONS OF WEARABLE GAMING TECHNOLOGY

Wearable technology is becoming increasingly popular in the gaming industry, and for good reason. From VR headsets to smartwatches, these devices are transforming the way we play games and interact with virtual worlds. Common applications include [12-14]:

- *Gaming*: Developers are all about creating and improving the gaming experience for players. Wearable technology in gaming uniquely focuses on enhancing the gaming experience. It offers a unique and innovative approach that differs from other industries, with a focus on immersion, interaction, and social experiences. There is an exceptional opportunity for contemporary game developers to build apps designed particularly for wearable devices that yield highly sophisticated gaming experiences for users. It is known that the gaming applications designed for wearable devices possess the capability to integrate built-in elements from the devices like gyroscopic motion sensing and gesture tracking to serve an interactive game experience. The integration of player movement into games has been quite a popular topic.
- *Mobile Gaming*: The world of wearable technology in mobile gaming is exciting. Wearable technology is becoming increasingly popular in the mobile gaming industry, and for a good reason. Mobile gaming technology has an advantage that it allows gaming beyond the stationary console. The flexibility of playing a game from anywhere is not appreciated enough when pointing out the impact of technology in the gaming world. So whether you are a seasoned gamer or just starting out, there is never been a better time to explore the world of wearable technology in mobile gaming.
- *Virtual Reality Gaming*: VR gaming is the application of a 3D artificial environment that allows gamers to transition from the real-world environment. Realistic and immersive simulation gives gamers a new twist to their user experience, allowing them to explore a game literally. VR games are at the forefront of wearable gaming, allowing players to enter entirely virtual worlds. With VR headsets, players can explore fantastical landscapes, engage in thrilling combat, and solve puzzles as if they were physically present in the game. For example, the Oculus Quest 2 is a standalone VR headset that offers an immersive gaming experience without the need for a PC or console. Its advanced motion tracking and high-resolution display make it a favorite among gamers. As VR gaming becomes more widespread (and affordable), hardware designers create new, more advanced wearables that enhance gameplay and track performance. An example of using VR headsets is shown in Figure 3 [15].
- *Augmented Reality Gaming*: Augmented reality allows gamers to play games with their immediate surroundings and computer graphics combined. You can use AR goggles for a more realistic experience or your phone's camera. AR games blend virtual elements with the real world, creating interactive and dynamic experiences. These games are typically played on smartphones or AR glasses, overlaying digital content onto the player's physical environment. AR Gaming made strides with the launch of mobile games like Pokémon GO, which blended virtual creatures with real-world environments through smartphone cameras. Pokémon GO players use their smartphones to hunt and capture virtual Pokémon creatures that appear in real-world locations, fostering a sense of adventure and exploration. AR glasses further extended these experiences, making them more interactive.
- *Fitness and Health Gaming*: Wearable tech is encouraging players to stay active and healthy. Fitness wearables and gaming have joined forces to make staying active enjoyable. Devices like VR headsets require physical movement, turning gaming into a form of exercise. Gamified fitness challenges and rewards incentivize players to move, promoting a healthier lifestyle and improved well-being. Fitness and health-focused wearables have transformed exercise into enjoyable gaming experiences. These games motivate players to stay active, offering challenges, rewards, and achievements based on their physical activities. Fitness wearables have turned workouts into exciting adventures, from running challenges to dance-based games.
- *Educational Gaming*: Wearable technology has found its way into education, providing interactive and immersive learning experiences. Educational games on wearables cover various subjects, making learning engaging and enjoyable for students of all ages. Educational software is developed with the overarching objective of making the process of learning more interactive, accessible, and effective for students.
- *Cloud Gaming*: Cloud gaming, also known as game streaming, allows you to play from a different device even as the actual game runs on the remote server. Just like storing your files on a cloud and accessing them from any device, cloud gaming offers the same benefits. Irrespective of the demands of a game, you can play it on any machine. Cloud gaming comes in



Figure 3: Using VR headsets [15].

handy for those that do not have access to the best gaming machines, like an expensive gaming PC.

- *Gamification:* Fitness trackers and smartwatches introduced gaming elements to encourage users to stay active. Gamification features, such as challenges, rewards, and achievements, add an entertaining aspect to fitness routines.
- *Entertainment:* The convergence of wearable technology and gaming has opened up new dimensions of fun and entertainment. VR headsets offer immersive gaming experiences, while AR glasses overlay digital content onto the real world, creating interactive and engaging gameplay. Wearable gaming, especially with virtual reality (VR) headsets, delivers an immersive experience like no other.
- *Immersive Esports:* Esports, derived from “electronic sports,” refers to competitive video gaming, where skill, strategy, and quick reflexes take center stage. It has taken the world by storm, and it is capturing more hearts and minds. This arena has transformed video games from leisurely pastimes into a multi-billion-dollar industry characterized by organized multiplayer video game competitions. Wearable technology in esports is improving athlete performance by offering detailed biometric data analysis during gameplay, including both physical and cognitive metrics. Today, esports captivate millions worldwide as participants and spectators, creating vibrant communities and pushing the boundaries of digital entertainment. The esports industry is a dynamic field experiencing rapid growth and widespread popularity, transforming competitive gaming into a global phenomenon. Tournaments are the backbone of the esports industry, showcasing the best talents worldwide in high-profile events that command significant viewership. Figure 4 shows an example of esports for entertainment [16].



Figure 4: Esports for entertainment [16].

VI. BENEFITS

Game developers now find themselves at the crossroads of exciting opportunities and unique challenges as they create games specifically tailored for wearable devices. One of the key advantages for game developers lies in the ability to explore and implement innovative gameplay mechanics that take full advantage of the unique features offered by wearables. The popularity of wearable technology can be attributed to its seamless integration into our daily lives, its focus on health and wellness, and the convenience it brings to various aspects of our routines. Other benefits of wearable technology in gaming include the following [14,17,18]:

- *Convenience:* Wearable devices are often more portable and convenient than traditional controllers, allowing players to enjoy gaming experiences on the go without the need for bulky equipment. Wearable devices like smartwatches and fitness trackers are handy. With information on your wrist, you can check notifications, track fitness goals, and even make payments with a simple tap. Wearables are a convenient remote for smart home devices. From adjusting the thermostat to controlling smart lights, wearables streamline home automation and make daily tasks more manageable.
- *Connectivity:* It is known that one of the key features of wearable technology is the capability to connect to the Internet, allowing data to get exchanged between the device and a network. Wearables allow for new ways to interact with games, such as using full-body movements or gestural controls.
- *Productivity:* Wearable tech is not just about enhancing gameplay; it can also improve productivity in other areas of life. For example, wearables can track performance metrics, helping players identify areas for improvement and develop their skills more effectively.
- *Personalization:* Customization or personalization as an important feature of wearables enhances the enjoyment of the technology, and increases the efficiency of use by customizing technologies to match the user's preferences. Games can be customized based on real-time player data, making for a more tailored experience. The ability to personalize, access real-time data, and combine fashion and function all contribute to the widespread adoption of wearables. Wearable devices cater to individual preferences and tastes. Whether it is customizing your watch face to match your mood or setting fitness goals, wearables put personalization in the palm of your hand.
- *Fitness Motivation:* Fitness wearables and gaming have joined forces to make staying active enjoyable. Gamified fitness challenges and rewards incentivize players to move, promoting a healthier lifestyle and improved well-being.
- *Social Interaction:* Sociability is a prominent wearable feature. The facilitation of social interaction has been an integral part of wearable design. Some wearable games embrace social elements, allowing players to team up or compete with friends in the same physical space. It fosters social bonding and adds a dynamic element to the gaming experience. Wearability and interactivity-related features facilitate the social value of wearables and social networking.
- *Artificial Intelligence in Gaming:* AI will revolutionize wearable gaming by creating dynamic and responsive gameplay experiences. AI algorithms will adapt games to individual players' preferences, skill levels, and behaviors, tailoring challenges and narratives for a truly personalized adventure.
- *IoT in Gaming:* The Internet of Things (IoT) plays a pivotal role in the integration of gaming wearable technology, empowering not only gamers but also game developers, designers, and manufacturers. IoT in the gaming industry leverages advanced software and hardware found in smartphones to create an oversupply of IoT gaming projects. As artificial intelligence and the Internet of things continue to

evolve, wearable technologies like the Tactigon will play an integral role in the ongoing improvement of user experiences across the gaming industry and beyond.

VII. CHALLENGES

Developing games for wearable devices comes with certain challenges, limitations, and design constraints. Mastering the controls and interactions in wearable gaming can have a learning curve, especially for newcomers to the technology. While wearable gaming can enhance social interactions in some cases, it may also lead to isolation as players become engrossed in their virtual worlds. Extended use of wearables like VR headsets can cause discomfort or even physical strain. Other challenges include the following [1,11]:

- **Cost:** High-quality wearable gaming devices can be expensive, limiting accessibility for some gamers.
- **Privacy Concerns:** As with any technology that collects personal data, privacy is a significant concern. Wearable tech for gamers often gathers sensitive information like biometric data, location, and usage patterns. Some companies may share data with third parties, raising ethical questions. Players need to be assured that their personal information is stored secure and used responsibly.
- **Limitations:** Wearable screens tend to be smaller, requiring developers to carefully consider the user interface and optimize the visual presentation to ensure optimal gaming experiences. Wearable devices may have limited processing power compared to traditional gaming platforms, which means developers need to optimize their games to ensure smooth performance and minimal latency. The wearable gaming market is still relatively young, which implies that there may be a limited number of games and experiences available compared to traditional gaming platforms. Not all devices are compatible with every gaming platform, limiting their usability.
- **Consumer's Taste:** Consumers' perceptions of the novelty of the wearable plays a key role in their adoption intention and purchase decisions. Generally, an ideal wearable needs to possess physical attributes such as being lightweight, aesthetically pleasing, its visibility and shape conformability, and multi-functional attributes such as configurability, responsiveness, and having a sufficient data bandwidth for interactivity. Wearability is defined as the notion of a device being wearable while the body is in motion, which addresses the physicality of wearing equipment and highlights that the wearer is the focus of the design in such devices. The factor of physical comfort and satisfaction comes as an important criterion for the ideal play experience.
- **Game Integrability:** This seems to be the most important module of wearables for leveraging gaming experiences. It represents wearables as being fully integrated with the game, meaning that the wearable can seamlessly provide interaction with the game and game mechanics, along with supporting role-playing and character identification.
- **Battery Charging:** Wearable gaming devices require regular charging, and their battery life may not always align with extended gaming sessions, leading to interruptions in gameplay. Many devices have limited battery life, which can disrupt gaming sessions.

The benefits and challenges of wearable gaming are displayed in Figure 5 [14].

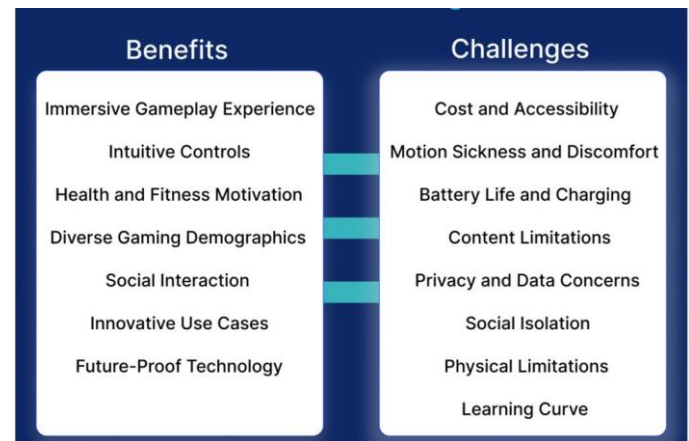


Figure 5: The benefits and challenges of wearable gaming [14].

VIII. FUTURE OF WEARABLE GAMING TECHNOLOGY

Innovative technologies that enhance the gaming experience have emerged over the years. The gaming world has evolved tremendously over the last decade. Wearable gaming devices are changing the way we interact with games, while expanding the boundaries of traditional gaming. Besides wearable devices, such as VR headsets, AR headsets, smart glasses, and smartwatches, some of the other groundbreaking technological innovations and devices that are also helping to take gaming to extraordinary new heights are motion tracking, live streaming capabilities, cloud gaming/computing, faster internet speeds, and artificial intelligence and its many tools. Wearable technology is undoubtedly a rising trend in game development. Gaming experts and professional gamers believe that software providers and hardware manufacturers will collaborate to craft even better products that will transform the face of online gaming in ways that we cannot yet imagine [15].

As wearable gaming technology advances, developers face new opportunities and challenges to create immersive experiences. We can only expect wearable technology to become even more influential, revolutionizing how we interact with the world around us. Emerging trends in wearable gaming are pushing the boundaries of immersive experiences and redefining how players engage with games. The future of wearable gaming promises to push the boundaries of interactive entertainment. It promises even more exciting developments as wearable technology continues to evolve, shaping the future of gaming experiences. Wearables such as wristbands and earbuds will soon double up as control devices for the fast-growing virtual reality (VR) and biometric gaming market as the technology becomes more accurate at recording data.

CONCLUSION

Wearable gaming is an exciting fusion of gaming experiences with devices like smartwatches, AR glasses, fitness trackers, and VR headsets. The integration of wearable technology into game development is emerging as a significant trend. Wearable gaming has transformed the gaming landscape, providing immersive, interactive, and personalized experiences. From fitness trackers to smartwatches and VR headsets to smart glasses, wearables have become integral parts of our routines. Wearable gaming's appeal transcends traditional gaming demographics. From kids exploring

augmented reality (AR) games to older adults enjoying fitness challenges, wearable gaming caters to many players.

Wearable technology continues to evolve, offering a glimpse into a world of gaming experiences that were once mere dreams. As technology advances, the gaming industry innovates and pushes boundaries. Developers face novel opportunities and obstacles to produce immersive experiences as wearable gaming technology develops. More information about wearable technologies in gaming can be found in the books in [19-21].

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