Journal of Soft Computing and Artificial Intelligence

Journal homepage: https://dergipark.org.tr/en/pub/jscai

International Open Access

Volume 04
Issue 02

December, 2023

Research Article

Embodiment in Virtual Reality and Augmented Reality Games: An Investigation on User Interface Haptic Controllers

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ARTICLE INFO

Article history:
Received December 24, 2023
Revised December 28, 2023
Accepted December 30, 2023

Keywords:
Embodiment
Virtual Reality
Augmented Reality
Gaming
User Interface
Haptic Controllers

ABSTRACT

Undoubtedly, virtual reality technologies stand out as one of the most rapidly expanding domains in the present era. Apart from features like clarity of vision, viewing angle and time distortion that are improving daily, user interfaces are another crucial part of this technology that is not talked about much but must be. This study investigates and summarizes the literature on wearable technology and haptic controllers, which serve as the player's interface between virtual and augmented reality. The controllers and devices we investigate, try to achieve a holistic approach in the experience thus it appears to be a rich soil for future studies. Although many technological advancements and entirely new ones are anticipated, a thorough analysis of the phenomena of interaction, participation, and integration, as well as embodiment and presence, should shed light on the question of its scope, depth, assessment, and limitations.

1. Introduction

The notion that digital environments could deliver a fully immersive experience has often been regarded as a "techno-fantasy" within the realm of science fiction [1]. Since game engines and 3D game universes are becoming more plausible and realistic than ever before, with the greater complexity of haptic technologies and interfaces based on natural bodily action patterns, creating an ideal standard for game design. It is apparent that games appeal to larger audiences as more people play them.

Juul claims that the rise in prevalence can be mainly attributed to the widespread acceptance of mimetic interfaces, where the player's physical actions closely mirror the in-game activities displayed on the screen [2]. Similarly, as Skalski et al. posit; controllers incorporating more intuitive mappings empower players to effortlessly connect with mental representations of real-world actions, thereby facilitating their immersion in the game [3].

De Castell with Jenson in The Entrepreneurial Gamer: Re-gendering the Order of Play, argue that game controllers designed in specific shapes and forms (e.g., a musical instrument) such as units with motion-sensitive sensors, provide different gaming styles and experiences [4]. Additionally, these formats appear to be used for educational purposes. In other words, digital interaction forms not only use a large part and or the entire body as a control unit, but also begin to transform human-computer interaction into a different point, with increasingly natural and mimetic movement forms. In addition, tactile feedback such as -frequently used- vibration can be considered to support the sense of digital embodiment.

According to Dourish, the evolution of human computer interaction has progressed through different phases, culminating in a transition from statical graphical user interfaces towards more concrete, communal, and incarnate methods. In

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DOI: 10.55195/jscai.1409156

particular, the concluding phase is advantageous in enhancing "the mechanics of daily living" and "the manner in which we encounter everyday life" [5]. The literary works articulates many opinions on the contributions and effects of technological equipment to the gaming experience. However, these views seem to be not sufficient to lead us to a conclusion. Similarly, Hufnal et al. affirm; "whether the gaming devices are the easiest to study and research, or the most realistic ones are 'more successful' is challenging to articulate and characterize to intricate interplay between human psychology, perception, and their interaction with engineering systems" [6].

2. Embodiment in Virtual Reality and Augmented Reality Games

Embodiment in games can also be thought of as "a concept in which players identify and experience themselves with the bodies of these characters while interacting with virtual characters". Players use body movements to perform actions in the game and transfer them to the character's body. In this process, players' perceptions, movements, and emotional experiences are reflected in the body of the virtual character, and players feel merged with the body of this character [2]. Embodiment allows players to fully immerse themselves in the game world and makes the gaming experience more intense and impressive. Players experience the game world through the body of the character they control. explore, interact with the environment, and perform tasks. In addition, embodiment can also be considered to help players gain a perception of presence in the virtual world with a deeper connection the game realm they experience [5].

Embodiment in games can be achieved through various technologies and interfaces. As motion sensors and virtual reality headsets allow players to transfer real body movements to the virtual character. These technologies provide more realistic and impressive aspect to embodiment experience. This concept also plays a significant role in game design. Game developers use mechanics, controls, and visual elements that support embodiment to enable players to connect with their characters. In this way, players become more deeply involved in the game world and cope with the challenges of the game using the character's bodily functions.

3. Aim and Contribution

There are currently a multitude of controllers for interacting with virtual environments and artificial reality, each with their advantages and limitations, as we stated earlier.

Although some controversial devices may not be successful in sales or are only at the prototype stage, it is possible to develop predictions about their potential and the contribution they will make to future academic studies. Additionally, in Lankoski's discourse "feedback from players and users also helps shape these predictions" [7]. So as instance, how can we replicate actions such as keyboard typing or using a scalpel in a simulation? Which technology offers the most intuitive user experience? What methods can be employed to create a sense of user immersion in the virtual world while facilitating interaction with the real world?

This research aims to cover the most recent research specifically on game experience with devices, wearable tech, and controllers with more natural mappings.

4. Embodied Interaction and User Interface Haptics

Virtual reality technologies are indubitably one of the fastest growing areas today. In addition to elements that are getting better day by day, such as clarity of vision, viewing angle and time distortion, another important aspect of this technology that is overlooked very often but merits consideration is user interfaces. Because these interfaces are the first station where the subject and the virtual (digital) environment meet. For decades the controllers and controllers of personal computers were limited to devices such as mouse and keyboards. Finally, contemporary approaches encompass a range of more advanced methods for controlling the virtual environment. In addition to traditional input tools like hands, alternative body parts such as our feet for navigating the virtual world of eyes for eye tracking even are now viable options.

However, according to Bernatchez and Jean-Marc, after years of getting used to two-dimensional computer planes, it can be initiating the process of contemplating three-dimensional movement and visualization can pose a challenge and may seem intricate for us [8]. Yet, adhering to Steven LaValle's Universal Simulation Principle, "any interaction mechanism occurring in the real world can be simulated in artificial reality" [9].

In the most recent literature review, Sudha et al. [10], Bachmann et al. [11], Perret and Poorten [12], Li et al. [13], Boletsis and Cedergren [14] and Tomáš Nováček and Marcel Jirina's research published in 2020 stand out [15]. Especially the studies of

Nováček and Jirina allegedly are among the most comprehensive studies in the field. Almost all studies conducted until their research published in 2020 are of daily use and prime importance to users, as most controllers and devices are a compendium of practical devices used by designers in industry, work simulators, human-computer interface research, or by ordinary individuals such as amateur developers, gamers, or researchers. Nováček and Jirina say "When discussing the controllers of a user interface, the opinions and experiences of ordinary users are important," in this regard. Because evidently the "effectiveness of the user interface controller can be gauged solely by the level of satisfaction expressed by users [15]. Their efforts substantiating this perspective encompass not only research articles and official technical specifications but also user reviews and comments from sources beyond academic realms.

Game controllers are commonly categorized based on two primary criteria: (i) whether they are hand-based or foot-based, and (ii) the technologies employed for measurements, such as optical or acoustic tracking as observed. Referred to as the 'digitalization of movement' in some sources, motion tracking technologies have gained popularity in contemporary literature. This popularity is attributed to their capability to capture natural movements, allowing users to walk, use their hands, and even fingers, with these actions seamlessly transferred to the virtual world. This technology plays a crucial role in creating virtual avatars in both virtual reality and augmented reality, contributing to a truly immersive experience an aspect our research also explores. Initially, our focus is on investigating the realm of hand-based or foot-based haptics. We initially, aim to investigate the hand-based or foot-based haptics.

In early 2000's Nintendo Wii had a surprisingly significant success compared to its era [16]. After this success, Kinect of Microsoft and PS Move of Sony also try using motion control (Figure 1).

Figure 1 Microsoft Wii Kinect and Sony PS Move

Despite this significant success, Leyvand et al. [17] claims that immersion without any intermediary controllers has long been considered "the holy grail of game designers and developers". However, assessments on platforms like Metacritic reveal that not all games effectively employ this type of interaction [18].

Optical tracking technologies, which provide gaming experiences without any intermediary controls, employ an imaging device, such as a camera, to monitor the user. The user's position is determined, and their movements are tracked by one or more sources typically mounted on the walls of the monitored room. These sources emit an optical signal, often in the form of infrared light, which is then captured by the imaging device.

Tjaden et al., divide gaming devices, which are widely used in the industry, into active and passive, depending on 'how the signal received from the user is sent to the device and processed'. And it suggests signals from active tracking as 'more precise' than passive optical tracking [19].

Especially, outside-in tracking technologies, frequently encountered in recent years in in-game immersion studies, takes an approach to adopt whole-body engagement by eliminating the necessity of a gaming input device [15]. These devices have the capability to track player movements in real-time and react to specific gestures and spoken instructions through an infrared sensor bar [19] and microphone. In this context, at first glance, it seems appropriate to address the phenomenon of embodiment, which was offered in Merleau-Ponty's phenomenological perspective on perception [20]. However, when investigated in depth, its obvious shortcomings become evident even as a mere 'tool'.

The most prominent device with this mechanic is initial iteration of Microsoft's Xbox Kinect, released in 2010, incorporates a RGB color video camera, a depth sensor, and an array of microphones (Figure 2).

Figure 2 Microsoft Xbox Kinect

This first-generation device is based on the principle of patterned light in which an infrared pattern is projected onto the user where it calculates the user's distance and movements by detecting deformations in the camera's perception pattern and identifies and monitors forty-eight key points on the user's body [21]. With this structure, it can metaphorically be considered as a 'third eye' without interfering with the player's in-game behavior. However, according to Cong and Winters, "Unfortunately, Kinect did not achieve commercial success, and even the sales of its second-generation successor are underwhelming" [22]. As a matter of fact, Microsoft halts product support after the second-generation Kinect, which relies on the Time of Flight (TOF) principle, involving the measurement of the time it takes for the signal to reach a tracked object and return to the source [21]. And within 2020, they launched a new sensor device, Kinect Azure. On this instance, the application is not for gaming but rather for industry and business. Sarbolandi et al. interprets this situation as such technologies being far from promising for the gaming world [23]. It is discernible in the literature that among the most utilized types of motion tracking systems that relies on optical sensors is ART-Advanced Real-time Tracking [24]. ART, which uses both active and passive functions and provides outside-in monitoring, has launched TRACKPACK products in 2015 for broader areas and SMARTTRACK 2019 for surface tracking.

The precision and precision of tracking depend on the number of tracking cameras and this aspect holds considerable promise for potential gaming research. It was first launched in 2012 under the name OptiTrack Primex 41 and then relaunched in 2020 with advancements [25].

The OptiTrack Primex 41 (2020, 2023) is preferred by game manufacturers and researchers due to its high tracking range and the ability for pairing with any OptiTrack Prime camera to establish an optimal setup. However, it is observed that this approach has not yet been sufficiently included in academic research.

In 2016, software company WorldViz launched the Precise Positional Tracking (PPT), a warehouse-scale tracking system [26]. What is distinctive about this system for game studies and our research is that its capability extends beyond WorldViz Vizard and includes support for game development engines like Epic Games' [27] Unreal Engine and Unity Technologies' software Unity [28], enabling interface integration as seen on Figure 3 below. In this mechanism, optical tracking can be refined by incorporating an acceleration-based tracking system, either integrated into the controller and/or attached as a clip to a Head-Mounted Display (HMD) [26].

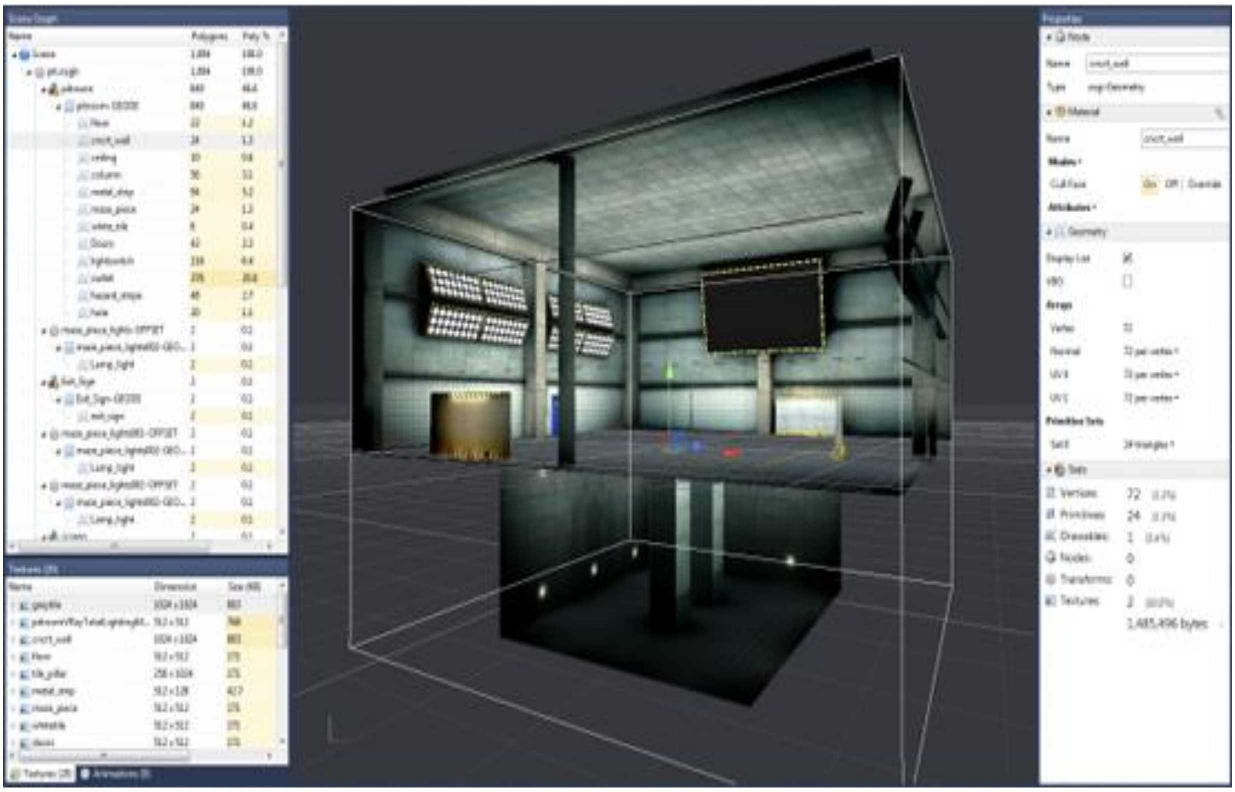

Figure 3 WorldViz Vizard Unity Interface Integration

Similarly, Vicon, one amongst the earliest systems according to scholarly works, provides a full-body marker, a kind of 'invisible suit of markers', to track users (Figure 4), [27], [28].

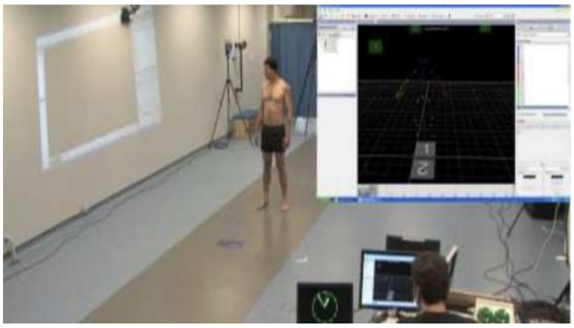

Figure 4 Vicon Application and Software Interface

However, compared to its beneficial use in the game industry, it has not yet been adequately addressed in academic studies.

Both Vicon and VR Tracker (2016) offer a tracking system that can operate wirelessly as well over a Wi-Fi connection, developed by the same software company, is also used in game research [28], Oculus VR's Constellation (2015) is also regarded as a tracking solution for Oculus Rift apparatus as seen in Figure 5 [29]. Yet some researchers, such as Durbin, states this system as 'low quality' [30].

PlayStation VR (2016), which has a similar operating pattern, also includes two camera bars to observe blue light strips on the headset and luminous spheres on Play Station Virtual Reality controllers [31].

The Lighthouse (2015) system, developed by Valve, is mainly developed for SteamVR and the HTC Vive, which was used for the experiment referred as a supplement as part of their study [32].

This type of monitoring structure is often 'erroneously' classified as outside-in monitoring in the literature [15]. Because in fact, this the setup utilizes two "base stations", which are boxes emitting infrared signals. The tracking process is performed by the device internally, moving from the inside to the outside.

Figure 5 Oculus Constellation Set

In 2019, HTC Vive Cosmos, which eschews the Lighthouse tracking system but has internal-external tracking, begins to be used. The headset has six built-in sensors, four on the front and one on each side, to scan forward, top, and bottom [32]. According to Machkovech, Lighthouse "promises backward compatibility" [33] for 2021 [34]; however, as of today, in December 2023, apparently it is still not been examined.

In 2019, Facebook develops a tracking system called Insight [35] integrated in conjunction with Oculus Quest from 2019, Oculus from 2020 and Oculus Rift S from 2019, the built-in cameras produce a 3D representation of the room as seen on Figure 6 below.

Figure 6 Oculus Rift integration with Facebook

The IMU (Inertial Measurement Unit) system monitors movements of the head and hands, and the controllers are equipped with infrared LEDs to enhance the precision of controller tracking [36]. In a way, this can also be interpreted as the proliferation of highly sensitive devices to interpret human movement (related to the ability to integrate with Facebook-derived software).

In 2016, Lyrobotix reports that it was working on NOLO, a system incorporating both acoustic and optical tracking methods has been described by Lang (2016). Given its design as a sphere that links to the headset, this system can be employed with various VR glasses. The supplied transmitter emits ultrasonic and laser signals throughout the room, interacting with a sphere equipped with receivers. The system then processes the signals and calculates the user's position. This system does not appear very often in the literature on game studies, but according to Lang; “the contribution of this system to the developments after it is undeniable” [37].

The variety of different approaches to intensifying the gaming experience shows that it is important to further develop the immersion and fluidity of virtual reality. According to Novacek and Jirina; “facilitating the player to move organically within the virtual world is of paramount importance” [15]. The fact that player is not restricted in any way, without having to wear some extra hardware on his head, on the screen, or whatever feels like an add-on [19], undoubtedly affects the experience [37].

In addition to systems that work from outside to inside, it is apparent that systems that cover the entire body, hands and feet are also becoming widespread. In their study “Synchronizing Data from Multiple Optical Sensors for Precise Hand Tracking”, Novacek and Jirina assert that “hand-based systems in particular dominate our working styles and that this trend does not seem to change in the near future” [15].

Nicole Murchinson and Robert Proctor in their 2013 assertion titled “Spatial Compatibility Effects with Unimanual and Bimanual Wheel-Rotation Responses: An Homage to Guiard (1983)”, refer to Yves Guiard’s 1983 theory. Accordingly, to deliver a completely immersive experience, the development of hand-based systems seems likely to be completed. However, manually operated systems are still relevant today and “will be relevant for a long time to come, because the hands are our primary tool”. It is obvious that our hands are the main means of interaction. [38].

However, according to Miriam Karam, “not every approach is sufficient for every application. In a virtual environment, a simple stick-shaped controller suffices to create the sensation of wielding a sword, where precision to the centimeter is not crucial when slaying a dragon. Whereas, in a virtual scenario where one takes on the role of a surgeon conducting a heart transplant, every millimeter becomes critical as it can determine the outcome between life and death [39].

The concept of sensitivity, which directly influences the sense of presence and embodiment, is not the sole crucial aspect of hand-based interaction. Novacek and Jirina, in their further study, interpret this as follows: “the input from the device not only enhances immersion and realism but also plays a crucial role in determining the application’s outcome” [15]. For instance, delivering haptic feedback is essential for the development of medical devices that empower doctors to perform surgical procedures through an interface linked to a physical device. Without precise and prompt haptic response, performing various procedures becomes challenging for doctors [9]. Of course, this application in gaming experience might be a tad different.

HIRO’s developers, Endo, Kawasaki, Mouri, Ishigure, Shimomura, Matsumura, and Koketsu, describe the system that “resemble basic controls such as a keyboard, mouse, or joystick, which are commonly employed in non-VR applications, or devices like 1994’s PHANTOM [40] or HIRO from 2011 [41] are utilized to govern the virtual environment created for VR. However, they offer a limited sense of immersion to users due to their inability to provide unrestricted movement yet “to create real-life-like structures with real modules” [42]. And there are apparent attempts to copy the physical keyboard into a hybrid virtual environment. In her 2006 dissertation, Maria Karam describes these physical systems as they serve as the primary type of handheld controllers for virtual reality, given their close resemblance to input devices used in the past. Simultaneously, “interaction using the human hand has proven to be the most intuitive compared to any other organ”. Slightly more advanced controllers provide haptic feedback [39].

Regarding to the user’s interaction and communication with an object in the virtual world, Chen, Chossat and Shull note that “when the user touches a wall”, for example, it may provide certain cues. They further explain that “the controller’s vibrations provide the most common and simplest form of feedback. More complex feedback can be achieved by force feedback of only parts of the controller in one direction” [43].

Certain handheld devices also seek to guide users’ motions, signaling when the next movement should occur or providing movement feedback based on physiological cues. However, these features are not widespread, and they are typically not used for managing the surroundings; instead, they solely offer response [44]. Examining this scenario within the broader context of holistic interaction, it becomes apparent that these capabilities may be deemed ‘insufficient’ to address the issue. Single-handed haptic controllers typically take the form of a wand, providing users with a straightforward means of controlling the virtual environment with one hand. While user-friendly devices, although more natural for many actions, fall short in supporting more intricate interactions as users cannot engage both hands simultaneously [45].

Most of the one-handed controllers are designed for basic tasks such as pointing, object selection, or teleportation within a virtual environment. In 2018 CLAW, which was created through collaboration with Stanford University and Microsoft Research Lab, provides three unique interaction modes: grasping virtual objects, touching virtual surfaces, and initiating actions [46] changes the corresponding haptic display based on how the user holds the controller as seen on figure 7.

Figure 7 CLAW

Additional haptic feedback methods include vibrations and force feedback, resembling the sensation of wielding a weapon in 2018, Choi et al. presented their research on this structure at the CHI - Human Factors in Computing System Conference [46]. Although it can be considered a limitation that it is designed only for the right hand, it is indubitably a convincing step for technologies that cover the whole body and promise more complete and enveloping weapons.

As a matter of fact, in 2018, Microsoft developed another controller in partnership with the University of Washington, the project was named Haptic Revolver. In this multi-purpose system, it allows for touching, cutting, texture and shape creation through a rotating wheel with various surfaces on its side. As an illustration, the user can perceive distinct sensations for a table and a poker chip on the table. Nevertheless, this setup, while somewhat distant from replicating real-life textures, could be seen as potentially impacting the immersion. Rotating the wheel allows the user to sense it gliding on the surface. The surfaces can be reconfigured by altering the wheel, and a solitary thumb button [47] is employed for making selections.

Haptic controllers such as the VR Gun Controller from 2019, on the other hand, are in the form of weapons, closer to the game and real-world matching, and are widely used in the game industry [48]. And it even promises a more natural match with the 2020 improved version [49]. Jean-Marc and Bernatchez in "A study on the impact of spatial frames of reference on human performance in virtual reality user interfaces", suggest that effort and interaction during play, just like exercise, are distributed in both hands. Moreover, in their "Impact of Spatial Reference Frames on Human Performance in Virtual Reality User Interfaces" study, they recognize whether the player's interaction takes advantage of the enhanced feedback offered by leveraging the individual's proprioceptive sense to facilitate a more seamless and faster interaction compared to a device that is used only with one hand [50]. This is undoubtedly a promising approach for immersive holistic experiences. According to Steam gaming platform data, "the most utilized for gaming experience could be HTC's Vive device [51]. The device's vibrations provide tactile feedback and can be used with one hand when necessary [52].

Microsoft has Windows Mixed Reality Motion Controller (2017), and HoloLens Clicker (2016) (Figure 8), which are like the Oculus Touch system [21].

Figure 8 HoloLens Clicker

The more recent Etee (2020), the controller without buttons, utilizes proximity sensors to detect finger movements and can consequently replicate complete finger movement in the virtual environment [53]. Input is accomplished solely through touch, movement, force, and the closeness of the finger to the controller, as depicted in the figure 9. In a way, it can be considered as one of the systems closest to real life experience.

Figure 9 Etee Screen

Finch Shift from 2017 interfaces the player with separate bands (called Finch Trackers) on player’s arms. Greenwald describes this structure as follows: “It combines information from the IMU units in the gloves, armbands, and headset mutually determine each other's positions, enabling the provision of 6 degrees of freedom (DOF) without the need for an additional external sensor [54]. Temoche, Ramirez and Rodrigez also generally interpret the fact that it includes wearable hand tracking systems, equipped with an array of sensors to “determine the position and bending of the hands and finger” are regarded as a ‘technological acceleration’ that brings virtual reality closest to a realistic sensation [55]. As noted by Li et al., “recognition accuracy is high because hands and fingers are directly tracked. However, wearable hand tracking systems are generally more expensive due to the complex technology used and the need for frequent calibration” [13]. Wearable devices are divided into various sections and groups, but this is beyond the scope of the research. The group including the examples we have examined in this section; the approach that is ‘useful for game research but not very common for the industry’ is those that use “microfluidic processing or image processing” [56].

With the demanding trend of to be able to ‘wear’ the controller on the body, handheld technologies distinguish themselves by incorporating systems that include a set of sensors capable of determining the finger and hand positioning, along with their degree of flexion [55]. Earliest example of haptic gloves recognized is VPL Data Glove that conveys information about hand movements to the computer system. In From DataGlove to DataSuit, Lasko-Harvill et al. [57] writes about the tracking system called Polhemus that supports the tracking systems for the haptic.

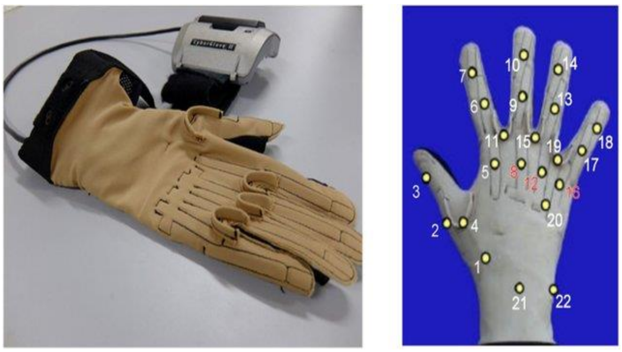

Figure 10 Cyber glove II

Contemporary CyberGlove Systems have been active since the 1990s and their project called Cyber Glove Series have been examined and analyzed in a “comprehensive calibrated database of kinematics for hand movements and grasps” by Jarque-Bou et al. in 2020 and as seen above in Figure 10, CyberGlove II and the positioning of the 22 sensors [58].

MANUS Machinae was founded in 2014 in Netherland and the first prototype Data Glove was successfully built. In 2017 they developed their first Development Kit Gloves DK1 and DK2 and in 2020 the company released the Prime II Gloves.

Alongside with a dedicated Xsens Glove by MANUS and subsequently the Prime X series gloves makes Polygon free to use for the creative community. And recently in 2022 the new gold standard Quantum MetaGloves seems to be leading the market [59] in the near future.

Although there are examples of research on the interaction of head and facial expressions other than hands [60], there are almost no concrete reports on the contribution of the player to the experience of immersion and presence in the game, it is currently seeming, as in the development phase ‘for the game field’. When we aim for physical and holistic participation in the sake of embodiment and complete presence, it is not enough for users to use only their hands and feet to provide a great immersion in the virtual world. The attempt to involve the whole body not only takes the immersion and embodiment the virtual world to another level, but also opens the way for research that seeks to find numerical values in terms of tracking. Another important feature of whole-body systems is the possibility of providing tactile encompassing the entire body; so that the player can perceive when kicking a sack or being shot, to illustrate [61].

According to Erin Martel and Kasia Muldner, with comprehensive internal medicine integrated into the virtual world, another facet involves leveraging the user’s physical functions with the body already equipped with sensors, it can also monitor the user's heart rate, perspiration, or electrical conductivity through their skin. This information could provide valuable insights into their fatigue levels or the level of enjoyment in the virtual world [62]. This approach allows for a more thorough and health-conscious evaluation of immersion and selected technologies.

One of the first ‘tactile’ suits that allowed control of the whole body while participating in the experience at the same time was the VPL DataSuit (1988), [57], seen in Figure 11 below.

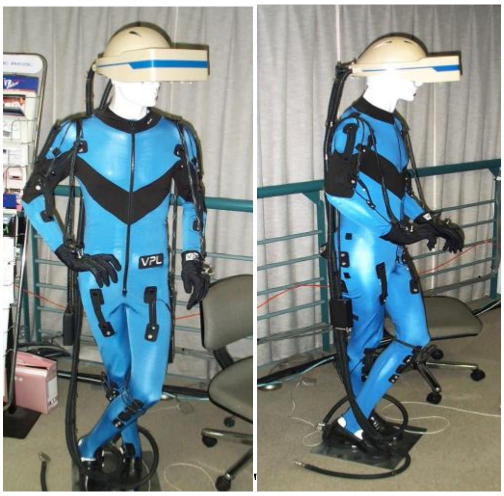

Figure 11 VPL Data Suit

The more recent HoloSuit Pro from 2018 and HoloSuit from 2020 are considered among the easiest to access and the earliest haptic suits that involves the whole body and parts of the body, available to the populace, not solely restricted to researchers. Besides its availability for use in sports, health, education, entertainment or industrial activities, there are almost no experiments in academic research [62]. And in the literature, various devices from the TactSuit (2017), along with the series of the tebHaptic company are also found [63].

Created specifically for the audio-based game Rez Infinite, Synesthesia Suit (2015) and (2020) provide not only vibratory feedback, but also game-appropriate sounds and colors; differing from its derivatives by combining image, sound, touch and promising something that did not exist until the 2020s. The creators of the HighFidelity VR [64] platform created the Exoskin haptic jacket [65] in collaboration with NeoSensory a technology manufacturer [66]. Another example is Hardlight Suit (2016) and Sinko (2017), developed by NullSpace VR [67], has some updated features but goes bankrupt later in 2018 [15]. It was launched in 2018 but today, in November 2023, no information about the product is available [68]. That same year, Disney designed a preliminary version of a haptic jacket with pneumatic actuation jacket known as the Force Jacket in partnership with Carnegie Mellon University and Massachusetts Institute of Technology.

DeLazio et al. states that; “this commodity is designed for specific gaming applications and has been officially launched in the market” [69]. While, University of Bristol researchers, defines this approach as “flawed”. The alternative Frozen Suit provides and enhances haptic feedback with stiffness patches that can prevent the movement of certain parts of the player’s body in the intended direction, that they claim is the best example of this system of the time [70].

Introduced by a Pakistani company Haptika in 2015, Haptika Vest also makes players feel the warmth of the virtual environment, is one of the technologies that we encounter in the literature [71] however, not a trace can be found about, today in 2023. It may be appropriate to say that this type of approach aims for a more comfortable, natural, and holistic immersion and complete embodiment experience that supports movements, includes other senses, and can be added to daily clothing without wearing any extra clothing or devices. Likewise, Perception Neuron Pro from 2019, [72] involves IMU sensors called several interconnected neurons positioned on the player’s body. The more neurons used, the more precise the experience will be. However, this comes at the expense of the fluidity of the in-game dynamics, as motion devices seem far from providing the real-life feeling of walking.

Human and movement are inseparable, and if the goal is the closest experience to reality, one should start with walking and jogging, which are among the most basic human movements. Naturally, the primary categories of movement devices fall into two types of treadmills: linear treadmill and omnidirectional treadmill. Additionally, there are devices without treadmills, such as motorized devices, user-operated devices, or pure walking.

However, incorporating sensors into such a system can be highly crucial. As Haruo Noma points out, ‘directly detecting and synchronizing’ [73] with walking speed is quite challenging, and a mechanical delay cannot be ruled out. Therefore, “the system must find a way to adjust the belt speed by using the user's position and walking speed as a reference” [73]. According to Campos and Bültoff, an alternative method for translating the player’s actual movement into the virtual environment involves the use of versatile treadmills [74]. These systems identify and offset the user’s walking movements, ensuring the user remains stationary regardless of the direction and speed of their movement, achieved through the counter movement of the device. For instance, according to Guizzo [75], the “CyberWalk from 2018, could involve a belt-based treadmill or conveyor roller” [74].

CyberWalk Projekt [76] that developed by German researchers at the Max Planck Institute for Biological Cybernetics has been essentially designed as a series of synchronized linear belts moving in one direction, enabling the player to enjoy greater freedom of movement compared to other platforms [75].

Campos and Bültoff discuss that “the drawback of the mechanism” [74] is when the user walks forward and stops, the treadmill continues to resist their movement, resulting in the user coming to a stop behind the center. One of the common aspects of these systems, each one follows the other and is more advanced than the previous one, can be considered as “the user moves his body even if he does not move on his own” as in another recent example; the Infinadeck [77].

KAT Walk supports different bodily functions and has smattering versions; KAT VR, KAT VR Premium and KAT VR Mini of 2016, 2017 and 2918 as seen below in Figure 12 and later in 2019 an advanced version KAT Loco.

Figure 12 KAT VR Walk

Its innovative design utilizes a mechanical arm and harness to support the player’s weight, rather than relying on a ring and multiple legs for stability [78]. The unique design involves the body being aided by a mechanical handle equipped with a harness capable of bearing their weight, as opposed to being suspended by a ring supported by multiple legs. Enough pressure is lacking from the strap for the wearer to feel uncomfortable because they are not hanging from it; rather, they are merely supported by it. In the virtual environment, users can run, crouch, jump, walk backwards, and walk. The action does not rely on a low-friction pad as it might make users feel unstable. Instead, it utilizes a surface made of high-traction material with consistent utilizing rolling friction to replicate genuine walking sensations.

While the most functional and promising discourse is seemed to be walking or running, for specific activities such as cycling or flying there will supposedly have to be specific devices that are designed for the specific activity VR Bike [79] not for gaming but for fitness-game purposes.

To summarize; not only for academic purposes or embodiment researchers in gaming but alternate reality labs, but also by business-oriented companies as well, develops and benefits from haptic controllers. The previous sections discuss the systems found in the literature and used as experimental research elements.

The earliest findings dates back to 1980s and literature suggests to refer to several articles such as; “Overview of Controllers of User Interface for Virtual Reality” [15], “Gesture Interaction in Virtual Reality” [13], “VR Locomotion in the New Era of Virtual Reality: An Empirical Comparison of Prevalent Techniques” [80], “Touching Virtual Reality: A Review of Haptic Gloves” [12], “Review of Three-Dimensional Human-Computer Interaction with Focus on the Leap Motion Controller” [42], “Approaches and Applications of Virtual Reality and Gesture Recognition: A Review” [10], “Visualizing the Keyboard in Virtual Reality for Enhancing Immersive Experience” [81] and “A Study on the Impact of Spatial Frames of Reference on Human Performance in Virtual Reality User Interfaces” [8]. Amongst the literary works, Novacek and Jirina’s research [15] can be considered as the most meticulously tailored yet not as summarized as ours and aimed specifically embodiment in Virtual Reality and Augmented Reality experiences.

5. Conclusion

Virtual reality technologies, along with game world and experience design, are on the rise at a rapid pace, and it is impossible to say which approach will prevail. However, the promise of such technologies is that they will affect important notions such as being ‘embodied’ in the virtual or augmented world, existing, and being surrounded. For instance, in the case of Kinect Star Wars, which holds 55 points from Metascore (accompanied by user rating of 3.6 out of 10), critiques highlight that nothing feels natural in the game. The movements, whether running, fighting, flying, or shooting, are described as 'subpar and extremely awkward'. The game is criticized for having a mechanical feel [18]. Another case in the study of Cohen et. al., similarly, reveals that "fighting is less fun than it should be, full of awkward, clumsy arm swings that don't make you feel like you're actually controlling the lightsaber" [82]. Thus, it is apparent that the controllers and devices we have discussed so far try to achieve a holistic approach in the process.

On the other hand, there are also studies that show that the feeling of immersion and embodiment is much higher when experienced only with a keyboard or mouse, without being experienced with the state-of-the-art intermediaries we have discussed here. So, can we experience the state of being surrounded and being present, which are 'internal' phenomena, directly and only with an 'external' effect through devices with more natural matches? The question would lead us to exceed the main scope of this paper but suggesting that future and ongoing research.

This paper investigates the literature on wearable technologies, haptic controllers that interfaces between the virtual and augmented realms and player. Numerous advances and brand-new technologies will arrive but by examining in depth the phenomena of interaction, participation and integration, embodiment, and presence, will presumedly provide insights to the question its depth, structure, evaluation and measurements and boundaries.

Acknowledgement

This present article was reproduced from the PhD thesis of the corresponding author Burçin Geniş-Ergün, under the advisory of Prof. Dr. Rıfat Şahiner, titled *"Immersion and Presence in Digital Games Through Merleau-Ponty's Phenomenology of Perception"*, at Yıldız Technical University, Art and Design Program, Istanbul, Türkiye.

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