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***Abstract*—Virtual Reality (VR) devices have undergone significant changes over the last years, transforming the way users interact with virtual environments. This paper presents a systematic review of VR and MR devices developed in the past five years, with a specific focus on their application within the entertainment and gaming industry. Our research entails an exhaustive systematic review of literature leading to the final selection of 41 papers. We build upon the taxonomy developed by Adilkhanov et al. [ARK22], adapting it to categorize the latest VR devices. Our findings reveal the diverse landscape of VR devices designed for gaming and entertainment. Subcategories highlight the complex choices available to users. This study reveals the absence of a standardized devices in the VR domain, emphasizing the need for further research to streamline and enhance user experiences in virtual environments.**

***Index Terms*—VR, MR, Devices, Categorisation, Systematic Review**

I. Introduction

The realm of haptic technology has witnessed remarkable growth in the past decade, driven by applications such as haptic robot teleoperation, virtual reality (VR), and mixed reality (MR). However, there remains substantial work to be done in enabling a fully immersive interaction with objects in virtual environments (VE). Achieving realistic object manipulation, including the perception of textures, shape, weight, softness, and temperature, is essential to enhance the immersion of users in the virtual world. Advancements in devices used in VR and MR are pivotal in complementing the visual and haptic experiences typically provided by several kinds of devices. Devices play a crucial role in providing feedback, enabling users to experience a sense of touch, often extending to the creation of haptic illusions. Some devices can also receive information from the virtual environment (VE) and relay feedback to the user, simultaneously transmitting the sensed position and force data of the user back to the VE.

This paper addresses a significant problem in the field of 3D interface devices, specifically within the realms of Mixed Reality (MR) and Virtual Reality (VR), with a particular focus on the gaming and entertainment industry. As the adoption of MR and VR technologies continues to grow, there is a pressing need for a comprehensive understanding of the latest developments in these domains. The problem at hand lies in the lack of a structured categorization framework for 3D interface devices, making it challenging for researchers and stakeholders to navigate and comprehend the rapidly evolving landscape of MR and VR technologies in entertainment. Without a clear taxonomy, it becomes difficult to identify the most frequently used devices and their applications within specific fields of the entertainment and gaming sector. This research seeks to address this problem by systematically categorizing and exploring the latest developed devices.

Following this, in chapter II related work is being presented. Afterwards, in chapter III the methodology section outlines the systematic approach used for the literature review. Discussing the search strategy, research questions, data collection, and the criteria for inclusion and exclusion. The paper then delves in chapter IV into the results, where the findings of the literature review are presented and the categorization of devices used in the domains of gaming and entertainment is being given. The importance of subcategorization is highlighted, shedding light on the nuances of user interactions with these devices. Finally, the paper concludes by summarizing the key takeaways from the study, emphasizing the significance of a structured categorization framework for researchers and industry professionals.

II. Related Work

In recent years, the landscapes of Virtual Reality (VR) and Augmented Reality (AR) have undergone significant transformations. Central to this evolution is haptic technology, which has redefined user immersion by facilitating tangible interactions within virtual environments. While we aim to focus on the advancements over the past five years, a groundwork for our study is the work of Adilkhanov et al [ARK22]. We used their taxonomy as a foundation of our categorization, which we discuss in Chapter in detail IV.

Adilkhanov et al. presented a unique and clear categorization system for haptic devices based on wearability. This taxonomy provided a easy to understand framework, making it easier to interpret the diverse range of devices and their respective applications. By grouping the devices by how they are worn, they laid a clear groundwork for classifying the haptic domain. In their work they used a systematic way to define relevant papers from major academic databases, filtering for those that introduced innovative concepts or offered new insights into haptic feedback and device modifications, and that were published from 2010 - 2021.

Laycock and Day [**?**] summarized the devices devices being developed back in 2003. They examined into the integration of haptic feedback with visual display devices, such as virtual reality walls and workbenches, to enhance the overall immersive experience. This can be seen as one of the foundations for the combination for visual and haptic devices.

Hayward et al. [HACH+04] presented a foundational classification of haptics in human-computer interfaces, covering human kinesthetic, tactile sensing, and existing haptic devices. Subsequent reviews have explored various aspects of haptic systems, including different taxonomies, design challenges,

and specific device categories like wearable haptics, glove-type wearables, and haptic gloves classified by design.

Culbertson et al. [CSO18] delved into the technologies that simulate artificial touch sensations. Their review emphasized the design, control, and application of non-invasive haptic devices, introducing a taxonomy that categorizes these systems into three main types: graspable, wearable, and touchable. Within each category, they explored various haptic feedback mechanisms. In a related work, Wu and Culbertson [WC19] innovated a haptic forearm sleeve using pneumatic actuation, which gives the wearer an illusion of lateral motion on the arm, achieved by a series of interconnected pneumatic actuators that create a continuous point of pressure.

This chapter highlighted some of academic literature researching VR and MR devices. The sources track the progressive advancements and innovations within the field. This chapter underlines the depth of research that has been conducted to evaluate and characterize these devices. Still there is now commonly settled categorization for devices used in this space.

III. Methodology

In the subsequent sections, we describe the methodology which was used to conduct the literature review in more detail.

A. Search Strategy

Our literature review followed a systematic approach presented by Kitchenham [Kit06]. The first step in our methodology was to search for existing literature reviews that focus the same topic. Throughout they years several attempts have been made as seen in Chapter II. The most recent attempt we found is the work of Adilkhanov [ARK22]. However, their literature review is focusing on devices used no matter the application. We in comparison want to focus on the entertainment industry specifically. Nevertheless, we used the taxonomy created by Adilkhanov as a first stepping stone to categorize the devices our literature review explored. We created a carefully crafted search term. The search term was designed to encompass the relevant literature to answer our research questions.

gaming OR entertainment OR recreation OR games

AND

VR OR virtual reality OR MR OR mixed reality

AND

wearables OR controller OR devices

B. Research Question

We embarked on this research in the realm of entertainment because it is often challenging to obtain a comprehensive and timely overview of the latest developments in a certain sphere. Our aim is to provide a categorization guideline that enhances the clustering of future devices, making it easier for researchers and stakeholders in the industry to understand and navigate the landscape of MR and VR technologies. Additionally, we are interested in identifying the most frequently used devices within specific fields of application, shedding light on the devices that are driving innovation and adoption in the entertainment and gaming sector.

RQ1 What are the developed devices in the last 5 years in Mixed Reality (MR) and Virtual Reality (VR), specifically focusing on entertainment?

RQ2 What are the most common devices researched in the field of gaming and entertainment and how could they be categorized?

C. Data Collection

We conducted our literature search by querying the IEEEXplore library[1], a well-known online database for computer science literature. This database was chosen due to its reputation and popularity among computer science studies. The initial search yielded a total of 699 results, representing potential sources for our review.

D. Inclusion and Exclusion Criteria

To narrow down our search results, we established a set of inclusion and exclusion criteria. These criteria were designed to ensure that the selected papers were both relevant and of high quality. Our inclusion criteria consisted of factors such as the publication date, the alignment with the research topic and that a device was described in the study. On the other hand, exclusion criteria was: papers were not written in English, were duplicate publications or had less than 4 pages.

IC1 Studies must be relevant to VR or MR
IC2 Studies must discuss a device

EC1 Studies where full-text is not accessible
EC2 Studies that do not propose or extend a device
EC3 Studies that are not related to VR or MR
EC4 Studies not written in English
EC5 Proceedings where relevant study could not be identified
EC6 Studies with less than 4 pages

E. Title Screening

The next step involved a preliminary title screening of the 699 results. To distribute the workload efficiently, each member of our research team was assigned approximately one-third of the total results. After the title screening, 573 papers were excluded, as they did not meet our research objectives or failed to satisfy the inclusion criteria, leaving us with a reduced set of papers for further analysis.

[1] https://ieeexplore.ieee.org/Xplore/home.jsp

F. Full Paper Evaluation

The remaining papers, totalling 126 articles, underwent a more thorough examination. During this phase, we manually filtered the content of each paper by reading the whole text. If a paper met all the inclusion criteria and did not meet any of the exclusion criteria, it was included. These assessments helped us in identifying the studies that would contribute devices to our literature review.

G. Quality Assurance

To ensure the validity of our review, we implemented a double-checking process. The papers that were included in our final selection were reviewed by another researcher of our team to confirm their suitability. Similarly, the papers that were excluded during the full paper evaluation were reviewed again by a different team member to reduce bias and the risk of excluding valuable contributions.

H. Final Selection

After our screening and quality assurance, a final set of 41 papers was identified as suitable for our literature review. These selected papers met our predefined inclusion criteria, demonstrated relevance to our research question by presenting a device related to VR or MR.

With this methodology we provide a systematic and transparent approach to conducting our literature review,.

IV. Results

In this section, ...

A. Overall Overview

Our initial aim was to capture a snapshot of the current developments of the entertainment and gaming industry, including its potential future trajectory. However, we also undertook a supplementary collection of health-related devices. We decided on this as even though our search term was not intended to find papers concerning health-related devices, the IEEExplore Library still provided papers in that field of research. This was considered as reasonable as it would also allow as to draw connections of possible evolutions of 3D interfaces from the healthcare sector into the entertainment sector.

However, we did not evaluate the health-related devices in detail only included them in our broad categorization, seen in Figure IV-B. A few reasons for this decision:

Health-related devices are designed for specialized tasks. Their functionalities and implications are vast, often requiring a detailed, domain-specific understanding which differed from our primary sectors of focus.

While one of our sub goals was to forecast future trends, the sheer breadth and depth of the health domain hinted at a vast potential that would be best addressed in a dedicated study.

Given these considerations, we believed it was in the best interest of the study's clarity and precision to focus on the domains outlined by our original search term: Gaming and Entertainment.

B. Broad Categorization

As mentioned we used the taxonomy by Adilkhanov et al. [ARK22] to get a first broad categorization of the devices we found during our literature review. In Figure IV-B the entries on the left in black are the categories developed by the other paper. We added some new categories, as we could not put every device we found into the existing categories. Therefore, we extend the taxonomy by adding the categories: "Camera", "Foot-worn" and "Skin-attached". Furthermore, we divided the devices into the categories: Gaming, Health, Music and Entertainment.

Now we discuss, the categories in more detail. Grounded haptic devices are typically too large or complex to be worn on the user's body. They often have limited workspace due to their stationary nature. Grounded haptic systems can be further categorized into graspable and touchable devices.

Graspable haptic devices are primarily kinesthetic and are known for their precision and ability to provide a wide range of forces. They are designed to mimic the sensation of grasping or manipulating physical objects in a virtual environment.

Touchable haptic devices are interactive displays that allow users to tactilely interact with objects shown on the screen. They typically offer pure cutaneous feedback through various actuation methods, making them suitable for applications like user interfaces and entertainment.

Camera-based devices use visual sensors and tracking technologies to capture and interpret the user's movements or gestures. These devices are used for applications such as gesture recognition, augmented reality, and 3D modeling.

Hand-held haptic devices can be picked up and held by the user without the need for body attachment. They are generally lighter and offer a larger workspace than grounded devices. They can provide both kinesthetic and tactile feedback.

Direct actuation hand-held devices operate directly on the user's hand through the handle and end-effector, providing haptic feedback through mechanisms.

Indirect actuation hand-held devices change the centre of gravity to deliver different haptic cues, allowing for the simulation of various virtual tools without requiring separate proxy objects.

Wearable haptic devices are designed to be worn on the user's body. They can provide various forms of haptic feedback, such as kinesthetic and cutaneous sensations.

Head-worn devices are haptic devices that are worn on the user's head, typically in the form of headsets. They are commonly used in virtual reality and augmented reality applications, providing immersive experiences.

Body-worn haptic devices are designed to be worn on different parts of the user's body other than the head. These devices can provide haptic feedback to specific body regions, enhancing the overall immersive experience.

Finger-worn haptic devices, often referred to as thimbles, focus on providing tactile stimulation to the fingerpads. They are particularly suitable for fine control and manipulation tasks involving the fingertips.

Arm-worn haptic devices are designed to be worn on the user's arms. They can provide haptic feedback to the arms and are used in applications that require simulating arm-related interactions.

Foot-worn haptic devices are worn on the user's feet and are used for simulating interactions related to the feet or lower limbs. They find applications in virtual environments involving walking or foot-based tasks.

Skin-attached haptic devices are directly attached to the user's skin, providing cutaneous feedback. These devices are often used for applications requiring precise, localized tactile sensations, such as medical training or virtual surgery simulations.

	Gaming	Health	Music	Entertainment
Grounded				
Grasp		[39]		
Touch			[4]	[38]
Camera	[10][21][37]			[18]
Hand-held				
Direct Actuation	[1][8][16][40]	[9][27][34]		[7][20][23][28][33]
Indirect Actuation	[37]			
Wearable				
Head-worn	[19][40]	[6][29][39]		[5][7][18]
Body-worn	[15][25]	[3][6][17]	[26][41]	
Finger-worn	[2]	[11]		[31][32][35]
Arm-worn	[13][22]	[14]		[36]
Foot-worn	[24]			[38]
Skin-attached				[12][30]

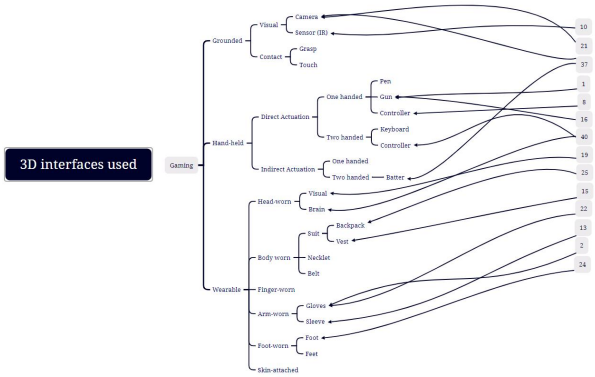
C. Devices in Music

The music category only consists of three entries. One of them is a Audino Foot Board used to enhance the experience while learning a new instrument [4]. While the other [26] and [41] used a device called Hapbeat...

D. Devices in Gaming

In the explanation and chart for the gaming landscape we have looked at 3D interfaces, especially as they address to virtual and mixed reality. To get a more detailed categorization we used the papers from our literature review to start a bottom-up categorization approach. However, as we knew from the categorization seen in Figure IV-B, we already settled on our categories which will be on top. Through a detailed bottom-up approach we have categorized these interfaces based on which body part used the device. To give a rough understanding of how that process looked like we do one example step-by-step. In [21] there is a camera used to do... . Therefore, we added the category "Camera". We repeated this process for each paper. Then we looked at similar devices. Therefore, we added "Sensor" [10] and "Camera" into the category of "Visual", which means that these device represent what they capture in a visual way. Due to this, we had to categorize "Touch" and "Grasp" into the "Contact" category, as these devices need some form of human touch to work. Both of these categories where eventually connected to the "Grounded" categories as we placed the devices before the subcategorization in that.

In the following, we only present some of the devices developed in the last 5 years. VR treadmill system (leap motion) coupled with a handheld 3D interface. The device is meant to be used for whole body and detect a leap when

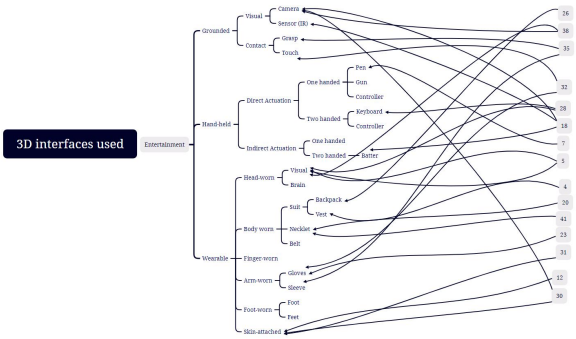


necessary. Gaming has added a new perspective on jumping over objects and it's a key movement on games these days. The sensors work simultaneously so the axis also can be changed with a little offset as well.

The design and implementation of a VR gun controller with haptic feedback. The gun(s) have a feedback motor and when attached to a real print of the gun added to visual devices will give the user experience like being in a real situation. Without the feedback it would feel more poor and have a lack of sensation. The motor it's self is quite simple creation but the way they have included it in a bigger entity makes it create a whole new level to the gaming.

Wack-a-mole styled hammer for games. The tool itself has a sensors, but it's also being tracked by cameras that have been grounded next to the system. The user can either see the gameplay happening on screen or by using a visual headset (VR). The second will create a more live-like experience due the high precision for it.

E. Devices in Entertainment



Haptic sensors for feet, can be used to define the motion of and placement. The sensors are meant to be used with two feet at the time but they also can be used individually for different kind of tasks.

A high-fidelity and high-precision multi-surface pen for virtual reality. With the pen the drawing does not only happen in a 2D space like we have been used to, it can also create objects and multiple different lines in 3D space making the visual outcome a lot of different compared to the normal pen that we are used to.

Soft microtubule muscle-driven 3-axis skin-stretch haptic device. The device tracks basically movement on a very high accuracy, so completing tasks with fingers like some different grips are made to be more normal and the feedback feels more like real life.

F. The Importance of Subcategorization

The importance of subcategories becomes evident when examining user interactions. While broad categories provide an overview of interface options, the subcategories offer tailored solutions that cater to individual needs. For example, within the realm of hand-held interfaces, choices extend beyond general preferences. Some users may favor a one-handed controller due to its ergonomic design, which can minimize arm strain and align better with natural postures. Others might gravitate towards a two-handed controller, valuing its stability and comprehensive button layout. By diving into these specific nuances, we can design interfaces that not only meet functional requirements but also prioritize user comfort and intuitive use. This meticulous attention to detail ensures enhanced usability and heightened user satisfaction.

Furthermore, the Figures IV-DIV-E show that there is no commonly settled device being developed in research. None of the subcategories in the gaming sphere contain more than two devices. This may indicate that there is still more room for growth as it seems that there is no optimal solution being found. This might also be caused by the fact that devices are individually created for a certain task. Therefore, there is no distinct pattern to see which devices are most commonly used in gaming or entertainment.

V. Conclusion

In conclusion, this paper delved into the rapidly evolving landscape of VR and MR devices. As the entertainment and gaming industry embraces the potential of immersive technologies, it becomes paramount to categorize and understand the latest developments in VR hardware. With a specific focus on the past five years, this study explored the latest innovations within that field. The research questions were addressed systematically through an in-depth literature review, resulting in the identification and categorization of devices.

Our methodology, inspired by Adilkhanov et al.'s [ARK22] taxonomy, helped structure the diverse field of devices, emphasizing wearability as a crucial categorization factor. Notably, our findings indicate that there is no universally established category for VR devices, suggesting a continued evolution in this domain. The subcategorization of devices also underscores the importance of tailoring solutions to specific user needs, promoting enhanced usability and user satisfaction.

As the VR industry continues to expand, with new devices continuously emerging, this research serves as a foundational guide for both researchers and industry stakeholders. By offering a clear and structured overview of VR devices, we aim to support the development of innovative and immersive technologies, ultimately enhancing user experiences.

We anticipate that future studies will further contribute to this evolving field. With the foundation laid in this paper, we encourage continued exploration and innovation using the developed in-depth categorisation.

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