# Challenges in HCI Design for Immersive Environments: A Systematic Literature Review

Gul Zaman Khan, Abid Ali, Shiraz Ahmad
Department of Computer Software Engineering University of Engineering and Technology Mardan, Pakistan

Muhammad Amin Khan
Department of Computer Science Cecos University of IT and Emerging Sciences Peshawar, Pakistan

Muhammad Ikram Ullah
School of software, Dalian Jiaotong University, Dalian 116028, China

Inam ullah
Department of Computer Science Abdul Wali Khan University Mardan, Pakistan

Hazrat Junaid[5], Fazli Rabi
[5]Department of computer Science and Information Technology, University of Malakand, Dir. Lower, Pakistan

Fouzia Sardar
Department of Botany University of Malakand Dir. Lower Pakistan

Shakir ullah
State Key Laboratory of Systematic and Evolutionary Botany (LSEB), Institute of Botany Chines academy of Sciences China

Afsha Jan
Department of English GDC Samarbagh

**Abstract:- Usability and design of various systems indicate how simply a computer may be managed to switch between various views and locate the pertinent information.Usability is crucial not only for measuring the ease of use of the software system, but also for identifying possible complications in the interface of software system. Human- Computer Interaction (HCI) focuses on making a system useable. If the structure, terminology, content, and searches for these systems aren't really easily accessible for their visitors, they will have little or no use. Interactions with these systems is only interesting if they are developed with polished features. Virtual environments are recreations designed to entice users into an artificially produced world, giving them the sensation of true presence. Interactive and immersive innovations include virtual reality, augmented reality, and truly immersive settings. Advances in HCI technology can lead to better virtual worlds (VW) and augmented reality (AR) experiences by providing more natural and effective ways for an user to engage with a virtually immersive experience. Despite the reality that there's been a lot of research conducted in the field of Human computer interaction for virtual elements, there are currently only a few studies on reviewing relevant literature HCI configuration issues for virtual elements.Following that, this study provides an inside and an outside review of work that explored several HCI configuration problems for virtual objects.The findings of our analysis HCI config issues for virtual elements and open exploratory challenges are presented and discussed in order to summarize the findings and recognize future inventive work in virtual elements. Usage represents one of the most important factors in determining the system's worth. The study will use related literature from around the world to study and evaluate the current state of quality assessment, design challenges, as it is a qualitative attribute, and to identify areas for development. This research looks into the efforts made mostly in design, usage, and design of efficient UI. Several sources, including large web collections.**

***Keywords***:- *UIDesign challenges in virtual systems, key challenges in usability of virtual systems.*

## I. INTRODUCTION

It has been said that human-computer interaction (HCI) is a computer-related cross-disciplinary field that is closely linked with the design of knowledge, interaction, and connection and that Inside this field of human-computer interaction (HCI), researchers regularly participate in the construction of research prototypes that are focused on theories derived from the behavioral and social sciences, psychology, and economics in addition to computing science. Making a system useable is a primary objectives of Human- Computer Interaction (HCI).If the structure, terminology, content, and searches for these systems aren't really easily accessible for their visitors, they will have little or no use [1]. Interactions with these systems is only interesting if they are developed with polished features**.** Virtual environments are recreations designed to entice users into an artificially produced world, giving them the sensation of true presence. [3].immersive invention refers to technology that combines computer-generated virtual objects and the actual environment with the help of continual intellectual ability and 3D registration, whereas virtual world communicates immersion depending on the external point of view.When real objects are combined with virtual objects in a real environment, wearable technology can be thought of as a subset of augmented reality. Previous studies suggest that system usability issues have been examined using several ways such as inspection-based techniques, user-based (user-testing) techniques, and tool-based techniques. Inspection-based strategies depend on professionals to detect design flaws throughout testing, whereas user-based strategies utilize surveys, interviews, and inspections to identify usability issues in a system. Applying third-party software techniques to identify a system's usability issues is one technique for evaluating tool-based methods. [1, 3] While VR is entirely imaginary, AR uses a real environment. While AR may be accessed with a smartphone, VR requires a headset device. Different scholars and scientists have defined the term virtual reality from that point on. For example, augmented reality is depicted by Sherman and Craig as a form of intelligent programmed experiences. In this type of medium, the placement and behaviours of the users, as well as alternatively the member, are identified to replace or enhance the comment to at minimum one identifies. Immersive and non-immersive virtual reality are available. Non-immersive vr is a form of virtual world where we interact with a virtual world through a smartphone or computer. We can interact with the environment through our personalities, but the environment doesn't communicate with us, such as in Real Life. Immerse vr technology, however, is the opposite of non-immersive vr technology. It ensures a realistic virtual experience that makes you feel that you are directly observable in the virtual environment and are experiencing what is occurring there. To provide a realistic virtual experience, specialized equipment such as Vr headsets, gloves, and body markers equipped with sensing identifiers is required. An example of an immerse setting is a caves. We broke down the various HCI design issues for all these immersive virtual worlds as the review's obligations.As a result, we identified many HCI research areas to investigate in order to come up with solutions to these problems in immersive settings. The figure 1 shows the usability testing of a system to measure the use of the interface of the system.

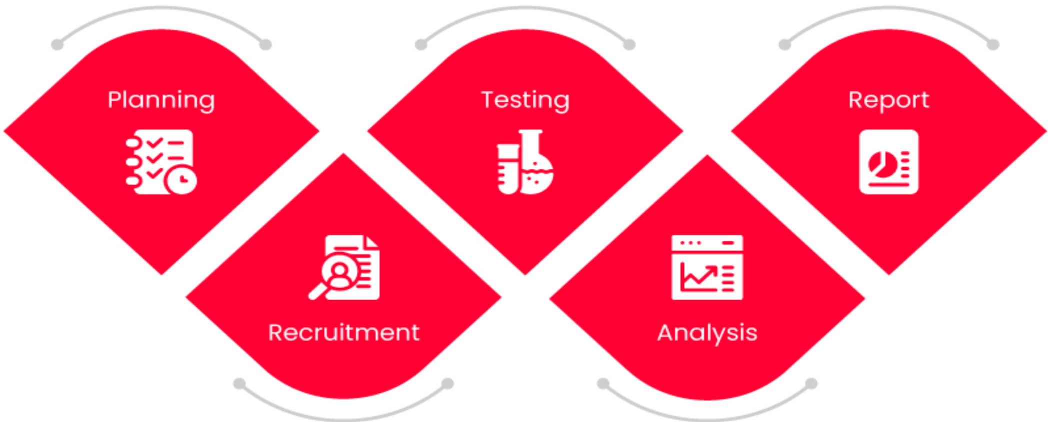


Fig. 1: Interface usability testing strategy

## II. RELATED RESEARCH

Various researchers did evaluations on HCI and immersive environments from different perspectives (Stanney, Mourant, Kennedy)[19].Learning and performance effectiveness, health and safety issues, and societal implications are the three main domains inside virtual environments where human-factors research challenges have been organized in this study. They also stress the need for VE technologies to be created with sufficient consideration for its people. .Another review was conducted by (Maryam Mousav, Yap, Siti) [20] .There review was based on cyber sickness and usability in virtual environments. Three concepts, according with authors, describe the rationale of cybersickness: (1) the sensual conflict hypothesis, (2) the postural instability theory, and (3) the poison theory. There are additional factors that are unrelated to the aforementioned notion, which including display and technological problems, target tracking errors, lag, and flickering concerns. In addition to the impacts of cyber sickness upon VE users, usability incorporates all the metrics used to examine the efficacy of a systems and human computer interaction in generally. Therefore, a vr - based system with great usability offers the user with unrestricted access and freedom in controlling and completing VE-based tasks. Similarly (Yuk Ming,Ka Yin)[21] conducted study about the use of virtual advancements in healthcare experience and development. The key findings indicated that virtual environment appeared to be a viable tool in clinical education and clinical practice. While it is evident from the studies that above it is necessary to study HCI design issues in virtual elements in order to highlight the principal difficulties in HCI Design and draw experts' interest in this area.

## III. METHODOLOGY

The purpose of a systematic study is to explore, analyze, and evaluate all potential research studies relevant to particular research topics, interests, or themes [40]. The related studies collected from the various databases to examine and evaluate the present state of usability testing, design concerns, which is a qualitative characteristic, and identify opportunities for development. This study examines the work that has been done in UI development, design, and usability.

Parts 3.1 and 3.2 discuss the research review process & technique used in the present study, covering review creation and implementation.

### *A. Design of the Review*

**We answered the three research questions listed below.**

- RQ1.Which HCI design issues exist in immersive world that are relevant to usability??
- RQ2**.**What are user interface issues for immersive world in Human computer interaction??
- RQ3**.**What difficulties does interactive immersive virtualization face??

In order to discover relevant studies to address the aforementioned research questions, we chose a variety of keywords.The chosen key phrases such as “HCI Design challenges”, “immersive technology,” “augmented reality,” “virtual reality,” and “mixed reality” were applied for collecting related articles.

**We searched for his keywords stated above in the below research publishing databases that enabled Boolean operator searches:**

- MDPI
- Google Scholar
- Semantic Scholar
- Science Direct
- ACM Digital Library
- IEE Explore

| Serial | KEYWORDS |
|---|---|
| 1 | Design And evaluation Issues & Truly Virtual Worlds & (Virtual World VR) & (Augmented Reality AR) |
| 2 | Difficulties and collaboration virtual systems & (virtual world ǁ VR) |
| 3 | Interaction design difficulties &( Augmented systems ǁ AR) |
| 4 | Menu layout and interactive settings present difficulties &(Virtual reality ǁ VR) |
| 5 | HCI &(virtual reality ǁ VR) & (Augmented reality ǁ AR) |
| 6 | User testing flaws &(virtual Reality ǁ VR)&( augmented world ǁ AR) |
| 7 | User Interface designflaws &(virtual world ǁ VR )&( augmented world ǁ AR) |

Table 1: Keyword used in literature search

Our comprehensive search technique included 3 phases: (1) an appropriate literature search, (2) the first phase, and (3) a second phase. During the first literature search, only English-language studies were obtained. Due to the minimal similarity between search queries and outcomes after a certain amount of discoveries from the literature databases, we only retrieved the first 200 papers for every keyword combinations that were ordered by relevance to the search queries. In the initial pass, the abstracts and the titles of the results of the original literature search were evaluated to determine whether they would be used in the second phase. We skipped those studies the name or summary did not state clearly related if the study has been about HCI design issues in immersive environments, augmented real world reality, or 3d virtual technologies, we scanned the rest of the article. Repeated or unrelated studies were discarded.We only considered research published papers in a peer reviewed journal or conference proceedings. As part of the second pass, we carefully studied the remaining studies' bodies, including the result and discussion, and evaluated them based on the following factors:

- Research that concentrates on word Human computer interaction design issues in virtual environment are counted in.
- Research that concentrates on word Human computer interaction design issues in VR/Aug., mix reality environment are counted in.

### *B. Conducting the Review*

We conducted a systematic literature review that was followed by the afore mentioned steps. The study had been carried out in three stages, which are detailed in the subsection: (1) study finding; (2) main study selection; & (3) data retrieval and analysis. Figure 1 displays the number of results discovered from each stage of the paper searching and filtering procedure.

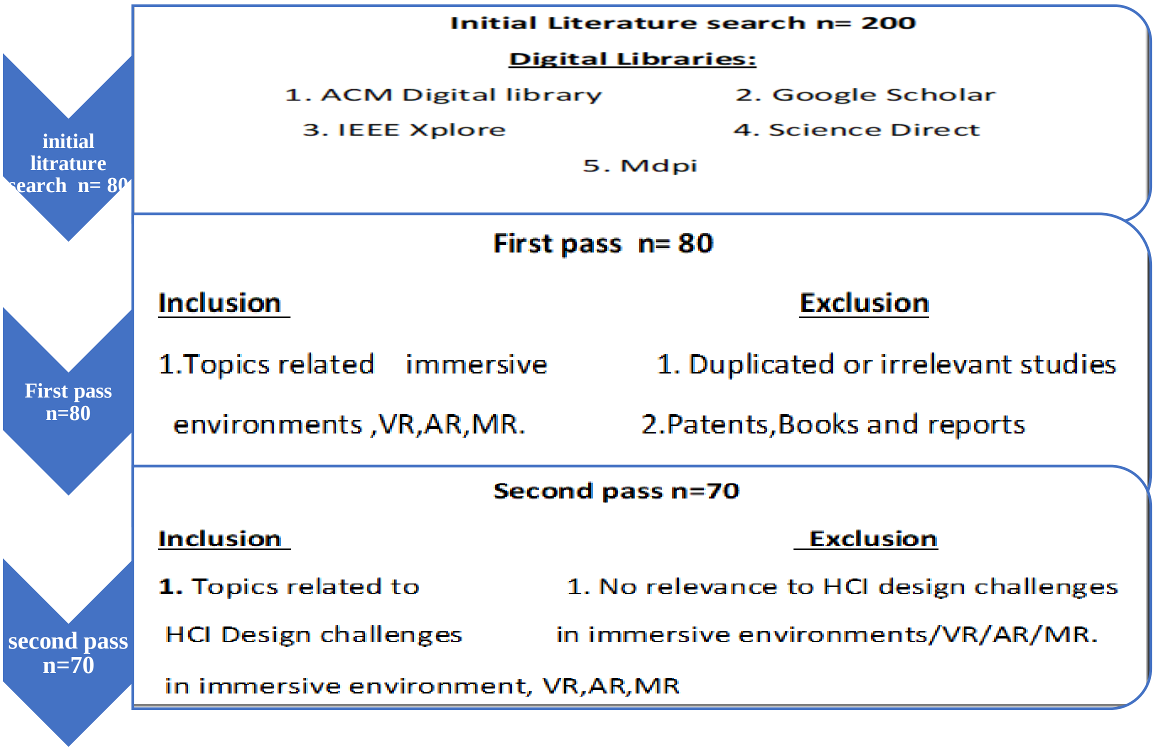


Fig. 2: The process of Literature search and findings

a) Identification of Research Studies: Earlystudies Search &First Phase
During this step we carried out the primary literature survey and the first phase to find pertinent research studies from the scholarly libraries indicated in Section 3.1.We looked for research that had been published and were written in English.We graded the search queries with either an A, B, or C from the more relevant to lowest relevant in order to order them according to their relevancy to the search queries. As a consequence, 200 studies were found in our first literature search on the specified databases. The subsequent filtering phase was conducted using selection and exclusion criteria in the first phase. In the initial round, we evaluated the obtained studies' names and summary. We looked at the study abstracts and title pages to see whether there was any discussion of virtual elements, AR, VR, or MR.We also examined study bodies when titles and summaries weren't enough Only scientific articles that had been through the process of peer review were considered for inclusion in the studies that were chosen by our team. Patents and other types of papers, such as books and reports, were not considered for inclusion in this research. In addition to this, we refined the results by omitting research that were either identical or irrelevant. As a direct result of this, 80 of the two 200 studies found in the literature search were successful in the first phase.

b) The Selection of Main Studies, with second phase Focus on Quality Assurance and Improvement
During the second drive, we eliminated studies that simply discussed immersive settings, AR/VR/MR, and did not address the Design and evaluation difficulties that are present in such settings. This allowed us to lower the total study number compared to the first phase. Due to the close relationship between these categories, we decided to include research that referred to virtual reality, augmented reality, or mixed reality rather than immersive environments. The second round of filtering resulted in the elimination of a total of 10 studies, which meant that the final decision consisted of 70 studies.We rated every paper ("yes" or "no") and removed those that didn't fulfill the criteria. Which verified suggested studies were applicable to our research problem. Unenlightening studies that cleared the second pass have been omitted by using criteria.

c) Acquisition of Data and Synthesis
In the "data extraction" step, the 70 studies chosen in the "quality assessment" step were thoroughly examined in order to obtain the information needed to provide responses to the study questions. We extracted publication date, title, year, authors, and study point. When we were capturing information throughout the review stage, we reproduced first text from the articles that were chosen so that we could reduce the impact that amendments had on the initial data. Following the completion of extracting features, we carried out information fusion in the form of the creation of a list that

ISSN No:-2456-2165

provided a concise summary of the findings obtained from information extraction in order to get answers to our research questions. Throughout the process of data synthesis for frameworks, our primary focus was on the difficulties inherent in the design of HCI across a variety of immersion frameworks. In order to provide a comprehensive summary of public research issues, the detected research directions challenges were arranged and combined into more substantial level research difficulties.

## IV. RESULTS

This section outlines 70 papers data analyses. Section 4.1 includes citation - based information and data statistics from examined papers, whereas Section 4.2 analyses HCI Design problems for virtual objects. Section 4.3 analyses HCI design issues. Section 4.4 summarizes the studies.

### A. *Statistics*

a) Database Distribution

Table 3 depicts the distribution of articles reviewed throughout our repositories. IEEE has the most studies, with 30. ACM digital library directory had 15 articles, Google Scholar 13, science direct 7, Semantic scholar 3, and MDPI 2.Figure 3 shows the distribution of papers from various repositories.

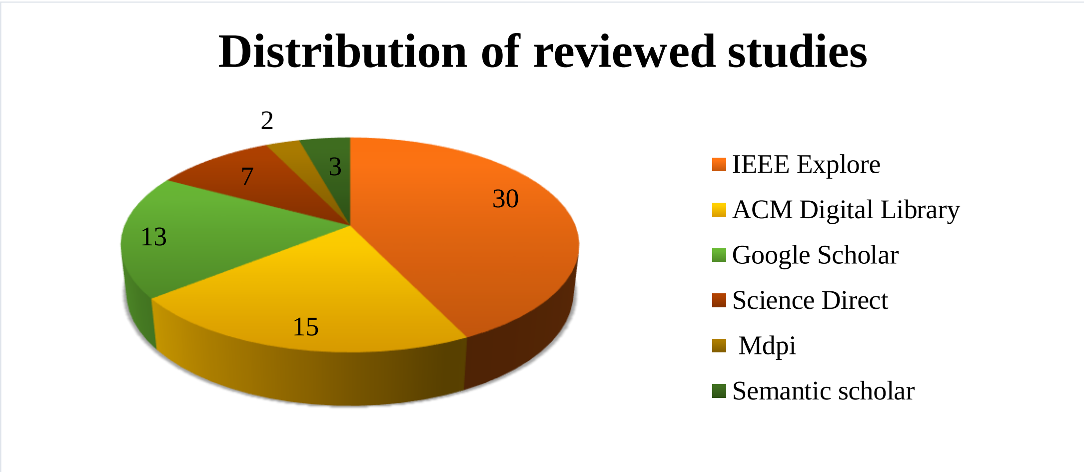


Fig. 3: Distribution of papers from various repositories

b) Yearly distribution

First, we investigated the citation - based data of the articles that were incorporated into the study. We came to the conclusion that the amount of research done on augmented reality and virtual reality has been fast increasing. The majority of the papers pertaining to vr technology were conducted in the past six years. Figure 4 shows the yearly distribution of various papers.

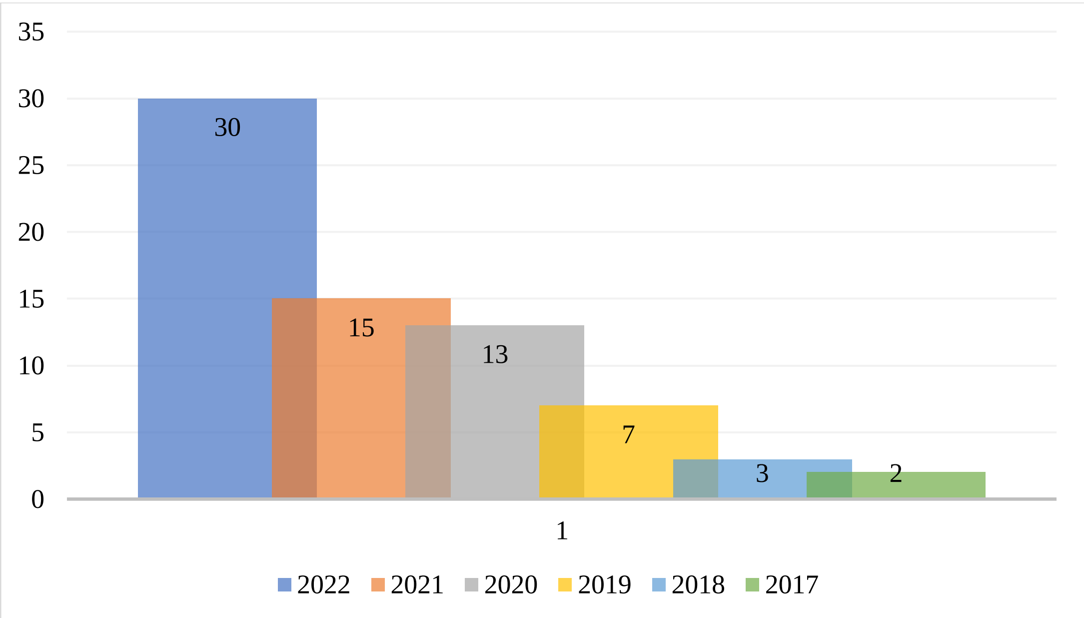


Fig. 4: Yearly Distribution

c) Result Analysis

As a result of our investigation, we were able to identify open research problems that were brought up in the papers that were examined. Issues in terms of the usability and layout were shown in Tables 2 and 3, respectively.

| **Framework Category** | **Issue** | **Measurement** |
|---|---|---|
| Technical | Usability | Learn-time, guidance, and psychological and physical comfort |
| Pedagogical | instructional Methods, Both General and More Specific Content | Coordination (including but not limited to turn-taking, conflict resolution, and engagement), adoption of avatars, and method comparison |
| Orientation | Alignment in space, direction, a sense of being there and being immersed, and feedback | It's time to fully submerge yourself in your surroundings and get used to them. |

Table 2: HCI design challenges related to usability

<table>
<tr><td>Keyword</td><td colspan="2">Challenge</td><td>Reference</td></tr>
<tr><td>User interface for immersive VE</td><td colspan="2">Usability, Menus Learn-time, instructions, and psychological and physical comfort</td><td>[4],[6],[12]</td></tr>
<tr><td>Gestural interface usability</td><td colspan="2">Good Gestural interface.</td><td>[7][21]</td></tr>
<tr><td>AR Technologies</td><td colspan="2">Dependency, Overload,</td><td>[7][11]</td></tr>
<tr><td>VR,<br>HCU, CAVE</td><td colspan="2">User interfaces with guidance<br>Imitate participation energy and tiredness? Running in VR vs. Real To enhance participant freedom, To minimize the need of an expert to run and operate a scenario virtual immersive environment</td><td>[7]</td></tr>
<tr><td rowspan="7">Augmented reality, challenges</td><td>Interface</td><td>Challenges</td><td rowspan="7">[9]</td></tr>
<tr><td>AR<br>Browser</td><td>Limited user engagement and motivation.<br>Non-adjustable user viewpoint.<br>Non-adjustable virtual content</td></tr>
<tr><td>3D User Interface</td><td>Require visibility for interaction.<br>• Smaller 3D UI in small display devices. • Lack of physical feedback.</td></tr>
<tr><td>Tangible User Interface</td><td>Difficulties in multitasking when holding TUI • Limited interaction area.</td></tr>
<tr><td>Natural<br>User<br>Interface</td><td>Restricted movement when using body sensors • Requires motion tracking accuracy.<br>• Some natural interaction techniques require training.</td></tr>
<tr><td>Multimodal<br>User Interface</td><td>Increases battery usage<br>Increases AR device weight.</td></tr>
</table>

Table 3: HCI design challenges related to interface design

| Keywords | Challenge | Reference |
|---|---|---|
| interaction, data visualization, immersion analytics, and virtual reality | Issues and challenges<br>Problems with the workflow Assessment collaborative virtual visualization prototypes. | [30] |

Table 4: Challenges in collaborative immersive environments

| **Keyword** | **Challenge** | **Reference** |
|---|---|---|
| reality into Virtual reality | persistence in submerging oneself Typing | [2] |
| Usability flaws in Augmented environments | Navigation | [4][11] |
| AR Technologies | Depth perceptions in AR and VR | [7][22][14][27] |
| Immersive analytics, Grand challenges | Prolonged usage for users. | [10][5][16] |
| HCI. VR interfaces, interactions | Interaction without intermediate devices | [11][10][13] |

Table 5: HCI design challenges related to usability

## V. DISCUSSION

Problems emerge concerning how to make utilization human understanding, cognitive abilities, and engagement capabilities; how to assist transition process around virtual elements; how to deal with the complicated geometries of immersive engagement for data processing; in addition to how structure spatial and cross feedback.[10]

The following inquiries are answered by our investigation of the difficulties inherent in HCI design when used in immersive settings:

5.1 RQ 1. Which HCI design issues exist in immersive world that are relevant to usability??

Table 3 lists numerous usability issues that we identified; these issues are detailed further.

### *A. Typing*

The initial concern with using a keyboard in Virtual is that it requires the user to find it in reality while within VR. Users must change their focus from their virtual world to the physical surrounding' spatial arrangement [2].

### *B. Perseverance of immergence*

When using an HMD, one's visual connection to the "outside" world is lessened, generating strong emotions of presence in the virtualized world. However, some interactivity with real items is frequently required. HMD displays are the biggest strength of VR settings. Users complained that they had to take off their headgear in order to use the keyboard, get a drink, or perform other necessary actions. [2].

### *C. Navigation*

While navigating users move through the virtual environment that surrounds them. Users, perceiving that they are moving virtually while they are still in reality, may experience an effect called motion sickness [21][25],or While wearing HMD our eyes perceive that we are moving while our body is immobile this produces motion sickness, Another of the problems that we find within the VR when navigating, is the spatial disorientation. This effect is produced when a user uses a navigation method that does not follow an optical continuity According to [4], navigation techniques produce spatial disorientation, as well as breaking the user’s immersion.

### *D. Prolonged usage for user*

There is a time limit for using immersive worlds, according to [10], because the user experiences eye strain [15], muscle weariness (shoulder/neck), pressure marks from the HMD, or the "gorilla arm" impression from strenuous exercise during engagement. [16].

### *E. Depth perceptions in AR and VR*

We discovered a consistent pattern of depth underestimate in the interior setting that is representative of virtual worlds and augmented reality systems. However, we discovered that participants overvalued depth in the outside setting, providing the user with inaccurate information.[7][13][14] Similarly in VR systems such as fish tanks Objects displayed with negative parallax on an edge of the viewing volume give rise to confusion in the depth perception of these objects. Although the object should be directly in front of the computer display, it frequently appears to be situated behind the display [26].

### *F. Interaction without intermediate devices*

Creating hand free movement is necessary to reduce the stress on users by allowing them to engage with the surroundings and move in virtual settings without having to use artificial markers, gloves, etc. [11] [12]. The concept of cognitive science has grown along with NUI breakthroughs. It is considered that moving your body can help to improve cognitive processes[23].

RQ 2.What are user interface issues for immersive world in Human computer interaction?

Table 4 lists many UI design issues that we identified; these challenges are described further below.

a) Menus

In immersive world basic task like displaying a "menu" becomes challenging in immersive situations, this does not constitute a fast forward movement in a 3D instance because the menu architecture and position are typically clearly specified for two dimensional interaction. Overlay, location, orientation, and selections are some difficulties that 3D menus must overcome.[3]

Additionally To enable precise actions, such as moving a slider to a specific place or choosing from a selection list, alternative glove interfaces or menus that "float" in space are needed.[5][17]

b) Good Gestural interface

A gesture-based ui has the ability to eliminate the dependence on pointing devices, reducing the amount of time in the process of communication. However, performing motions for lengthy periods of time can be extremely taxing, therefore a great gesture interface must be designed to reduce physical stress and exhaustion and used as an alternative to or in addition to existing interface techniques. [6][2] Also to develop such an interaction that uses light-weight wireless devices for gesture, such as wireless ergonomically devices [27[30], because these devices need not produce any constraints on user movement.

c) Overload and over reliance

Aside from the technical challenges, the user interface needs to adhere to certain guidelines in order to avoid overwhelming the user with information and to stop the user from becoming overly dependent on the augmented reality system, which could cause them to miss important cues from the surrounding environment. [7][18].

d) Guided and real interface design

An interface must be created in such a manner so that there is independence for the person involved in the surroundings and his power is not easily easily lost, correspondingly, a method for making waking in virtual world near to real as walking in real is significantly stronger than in virtual worlds as it has simplicity, straightforwardness, and genuineness which are not present in Virtual environments [29]. Additionally, the user interface was developed in such a way that it guides the participant through the process of running and operating the scenario, eliminating the need for an expert to be there. [8], including the use of 3D maps for navigation, which appears to be beneficial in terms of the amount of time needed to complete a task [28].

e) Challenges in AR user interfaces
There are different type of user interfaces each with its own set of challenges [9]

a. AR Browser
- Limited user engagement and motivation.
- Non-adjustable user viewpoint.
- Non-adjustable virtual content

b. 3D User Interface
Require visibility for interaction.
- Smaller 3D UI in small display devices.
- Lack of physical feedback.

c. Tangible User Interface
Difficulties in multitasking when holding TUI
- Limited interaction area.

d. Natural User Interface
NUI have many advantages as discussed [23] but NUI is also facing challenges discussed in [9] such as: Restricted movement when using body sensors
- Requires motion tracking accuracy.
- Some natural interaction techniques require training

e. Multimodal User Interface
There are various advantages of using multimodal approach in immersive environments, but the main advantage is that multimodal interfaces enable people with special needs to access computers easily and efficiently [24] but there are some challenges faced by researchers such as mentioned in [9]
- Increases battery usage
- Increases AR device weight.

f. RQ3.What difficulties does interactive immersive virtualization face??
Challenges in collaborative immersive environments are divided into three groups [31]
- Technical challenges
- Workflow challenges
- Evaluation collaborative immersive visualization prototypes

g. Technical issues
- Networking
- Registration & Hologram sharing
- Framework extensibility & performance.

h. Workflow Challenges
- Interaction.
- Awareness
- Persistence & Transitions

## VI. CONCLUSIONS

In this research, we carried out a comprehensive review of the HCI literature. For this study, we thoroughly reviewed the literature to determine the HCI design challenges in immersive settings. After searching multiple papers using similar terms across various databases, we discovered 70 studies that fit our criteria. We carefully reviewed each study in order to determine the answers to the research questions that were introduced at the start of this extensive literature analysis. We did a thorough examination and found that different research had different usability and interface design problems. We then carefully discussed our data in order to come up with answers to the questions we had for our study. We believe that by identifying the research areas that should be focused in future studies, our results can assist researchers.

## REFERENCES

[1.] Sherman, W., & Craig, A. (2003). Understanding Virtual Reality—Interface, Application, and Design. Presence: Teleoperators And Virtual Environments, 12(4), 441-442. https://doi.org/10.1162/105474603322391668

[2.] McGill, M., Boland, D., Murray-Smith, R., & Brewster, S. (2015). A Dose of Reality. Proceedings Of The 33Rd Annual ACM Conference On Human Factors In Computing Systems. doi: 10.1145/2702123.2702382

[3.] Sziebig, G., & Øritsland, T. (2012). Navigating in 3D Immersive Environments: a VirCa usa bility study. IFAC Proceedings Volumes, 45(22), 380-384. doi: 10.3182/20120905-3-hr-2030.00141

[4.] Forte, J., Vela, F., & Rodríguez, P. (2019). User experience problems in immersive virtual environments. Proceedings Of The XX International Conference On Human Computer Interaction. doi: 10.1145/3335595.3336288

[5.] Lindeman, R., Sibert, J., & Hahn, J. (1999). Towards usable VR. Proceedings Of The SIGCHI Conference On Human Factors In Computing Systems The CHI Is The Limit - CHI '99. doi: 10.1145/302979.302995

[6.] Cabral, M., Morimoto, C., & Zuffo, M. (2005). On the usability of gesture interfaces in virtual reality environments. Proceedings Of The 2005 Latin American Conference On Human-Computer Interaction - CLIHC '05. doi: 10.1145/1111360.1111370

[7.] Van Krevelen, D., & Poelman, R. (2010). A Survey of Augmented Reality Technologies, Applications and Limitations. International Journal Of Virtual

Reality, 9(2), 1-20. https://doi.org/10.20870/ijvr.2010.9.2.2767
[8.] Muhanna, M. (2015). Virtual reality and the CAVE: Taxonomy, interaction challenges and research directions. Journal Of King Saud University - Computer And Information Sciences, 27(3), 344-361. doi: 10.1016/j.jksuci.2014.03.023
[9.] Ghazwani, Y., & Smith, S. (2020). Interaction in Augmented Reality. Proceedings Of The 2020 4Th International Conference On Virtual And Augmented Reality Simulations. https://doi.org/10.1145/3385378.3385384
[10.] Muhanna, M. (2015). Virtual reality and the CAVE: Taxonomy, interaction challenges and research directions. Journal Of King Saud University - Computer And Information Sciences, 27(3), 344-361. doi: 10.1016/j.jksuci.2014.03.023
[11.] Vultur, O., Pentiuc, S., & Lupu, V. (2016). Real-time gestural interface for navigation in virtual environment. 2016 International Conference On Development And Application Systems (DAS). doi: 10.1109/daas.2016.7492592
[12.] Kharoub, H., Lataifeh, M., & Ahmed, N. (2019). 3D User Interface Design and Usability for Immersive VR. Applied Sciences, 9(22), 4861. doi: 10.3390/app9224861
[13.] Kruijff, E., Swan, J., & Feiner, S. (2010). Perceptual issues in augmented reality revisited. 2010 IEEE International Symposium On Mixed And Augmented Reality. https://doi.org/10.1109/ismar.2010.5643530
[14.] Livingston, M., Zhuming Ai, Swan, J., & Smallman, H. (2009). Indoor vs. Outdoor Depth Perception for Mobile Augmented Reality. 2009 IEEE Virtual Reality Conference. https://doi.org/10.1109/vr.2009.4810999
[15.] Kramida, G. (2016). Resolving the Vergence-Accommodation Conflict in Head-Mounted Displays. IEEE Transactions On Visualization And Computer Graphics, 22(7), 1912-1931. doi: 10.1109/tvcg.2015.2473855
[16.] Hincapié-Ramos, J., Guo, X., Moghadasian, P., & Irani, P. (2014). Consumed endurance. Proceedings Of The SIGCHI Conference On Human Factors In Computing Systems. doi: 10.1145/2556288.2557130
[17.] Bowman, D., & Wingrave, C. Design and evaluation of menu systems for immersive virtual environments. Proceedings IEEE Virtual Reality 2001. https://doi.org/10.1109/vr.2001.913781
[18.] Vlahakis, V., Ioannidis, N., Karigiannis, J., Tsotros, M., Gounaris, M., & Almeida, L. et al. (2001). Archeoguide. Proceedings Of The 2001 Conference On Virtual Reality, Archeology, And Cultural Heritage - VAST '01. doi: 10.1145/584993.585015
[19.] Stanney, K. M., Mourant, R. R., & Kennedy, R. S. (1998). Human factors issues in virtual environments: A review of the literature. Presence: Teleoperators and Virtual Environments, 7(4), 327–351. https://doi.org/10.1162/105474698565767
[20.] Mousavi, M., Jen, Y., & Musa, S. (2013). A Review on Cybersickness and Usability in Virtual Environments. Advanced Engineering Forum, 10, 34-39. doi: 10.4028/www.scientific.net/aef.10.34
[21.] Jinjakam, C., & Hamamoto, K. (2012). Simulator sickness in immersive virtual environment. The 5Th 2012 Biomedical Engineering International Conference. https://doi.org/10.1109/bmeicon.2012.6465465
[22.] Onishi, A., Nishiguchi, S., Mizutani, Y., & Hashimoto, W. (2019). A Study of Usability Improvement in Immersive VR Programming Environment. 2019 International Conference On Cyberworlds (CW). https://doi.org/10.1109/cw.2019.00073
[23.] Moon, J., & Ke, F. (2016). Categorization of Embodied User Interface in Immersive Virtual Environment. 2016 IEEE 16Th International Conference On Advanced Learning Technologies (ICALT). https://doi.org/10.1109/icalt.2016.31
[24.] Kim, H., Suh, K., & Lee, E. (2017). Multi-modal user interface combining eye tracking and hand gesture recognition. Journal On Multimodal User Interfaces, 11(3), 241-250. https://doi.org/10.1007/s12193-017-0242-2
[25.] Stanney, K. Realizing the full potential of virtual reality: human factors issues that could stand in the way. Proceedings Virtual Reality Annual International Symposium '95. https://doi.org/10.1109/vrais.1995.512476
[26.] Mulder, J., & van Liere, R. Enhancing fish tank VR. Proceedings IEEE Virtual Reality 2000 (Cat. No.00CB37048). https://doi.org/10.1109/vr.2000.840486
[27.] Hegie, J., Kimmel, A., Parian, K., Dascalu, S., & Harris, Jr., F. (2010). WiELD-CAVE: Wireless ergonomic lightweight device for use in the CAVE. Journal Of Computational Methods In Sciences And Engineering, 10(s2), S177-S186. https://doi.org/10.3233/jcm-2010-0277
[28.] Haik, E., Barker, T., Sapsford, J., & Trainis, S. (2002). Investigation into effective navigation in desktop virtual interfaces. Proceeding Of The Seventh International Conference On 3D Web Technology - Web3d '02. https://doi.org/10.1145/504502.504513
[29.] Usoh, M., Arthur, K., Whitton, M., Bastos, R., Steed, A., Slater, M., & Brooks, F. (1999). Walking > walking-in-place > flying, in virtual environments. Proceedings Of The 26Th Annual Conference On Computer Graphics And Interactive Techniques - SIGGRAPH '99. https://doi.org/10.1145/311535.311589
[30.] Deligiannidis, L., & Larkin, J. (2008). Navigating inexpensively and wirelessly. 2008 Conference on Human System Interactions. https://doi.org/10.1109/hsi.2008.4581427
[31.] Isenberg, P., Elmqvist, N., Scholtz, J., Cernea, D., Kwan-Liu Ma, & Hagen, H. (2011).Collaborative visualization: Definition, challenges, and research agenda. Information Visualization, 10(4), 310–326. https://doi.org/10.1177/1473871611412817

[32.] Adams, C., Nash, J.B.: A Usability Evaluation Method for Virtual Reality User Interfaces Sutcliffe A.G. and Diol Kaur K. J. Multi. Evil. 12 (26), 12–17 (2016). *

[33.] Agrawal, A., Boese, M.J., Sarker, S Designing the user interface: strategies for effective human-computer interaction. In: AMCIS, p. 523 (2010).

[34.] 4. Aryana, B., Øritsland, T.A.: Culture and mobile HCI: a review. In: Norddesign 2010 Conference, pp. 217–226 (2010). * 5. Baines, T., Lightfoot, H., Williams, G.M., Greenough, R.: Usability Evaluation for Drone Mission Planning in Virtual Reality. Mech. Eng. Part B: J. Eng. Manuf. 220(9), 1539–1547 (2006). *

[35.] Bellotti, V., Shum, S.B., MacLean, A., Hammond, N.: Application of virtual reality technologies in consumer product usabilitypp. 146–153. ACM Press/Addison-Wesley Publishing Co. (1995). *

[36.] Brooks, F.P.: The Design of Design: Essays from a Computer Scientist. Person Education, London (2010) 9. Brown, T.: Change by Design: An investigation into the implementation of virtual reality technologies in support of conceptual design, New York (2009). *

[37.] Brown, T.: Harvard Business Review: Design Thinking. Harvard Business School Publishing Corporation, vol. 86, pp. 84–92 (2008). *

[38.] Bellotti, V., Shum, S.B., MacLean, A., Hammond, N.: Application of virtual reality technologies in consumer product usabilitypp. 146–153. ACM Press/Addison-Wesley Publishing Co. (1995)

[39.] Baines, T., Lightfoot, H., Williams, G.M., Greenough, R.: Usability Evaluation for Drone Mission Planning in Virtual Reality. Mech. Eng. Part B: J. Eng. Manuf. 220(9), 1539–1547 (2006). *

[40.] Akoumianakis, D., Stephanotis, and C.: Universal design in HCI: a critical review of current research and practice. In: Engineering and Construction, p. 754 (1989)

[41.] ohnson, C., 1998. On the problems of validating desktop VR. People and computers XIII, Proceedings: HCI'98, Sheffield 1–4 September 1998, Springer, Berlin, pp. 327–338

[42.] Kalawsky, R.S., 1999. VRUSE: a computerised diagnositc tool for usability evaluation of virtual/synthetic environment systems. Applied Ergonomics 30(1), 11–25.

[43.] Kalawsky, R.S., 1999. VRUSE: a computerised diagnositc tool for usability evaluation of virtual/synthetic environment systems. Applied Ergonomics 30(1), 11–25.

[44.] Nielsen, J., 2000. Designing Web Usability: The practice of Simplicity, New Riders. Nielsen, J., Molich, R., 1990. Heuristic Evaluation of User Interfaces, SIGCHI Bulletin, April: Special Issue, pp. 249–256.

[45.] Ravden, S., Johnson, G., 1989. Evaluating Usability of Human-Computer Interfaces, Ellis Horwood, New York. Slater, M., Usoh, M., Steed, A., 1995. Taking steps: the influence of a walking technique on presence in virtual reality. ACM Transactions on Computer-Human Interaction 2(3), 201–219.

[46.] Slater, M., Linakis, V., Usoh, M., Kooper, R., 1996. Immersion, presence and performance in virtual environments: an experiment using tri-dimensional chess, Available online at http://www.cs.ucl.ac.uk/staff/ m.slater/Papers/Chess/index.html