Journal of Advances in Developmental Research (IJAIDR)
E-ISSN: 0976-4844 ● Website: www.ijaidr.com ● Email: editor@ijaidr.com

Ensuring Consistent VR User Experience across Multiple Platforms

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Abstract

Developing a VR compatible with numerous hardware, inputs, tracking, and rendering approaches has become challenging. Since computers differ in their processing speeds and graphics cards, graphics display and screen refresh rates vary, and so does the quality of the controllers that can be used to operate the computers. With no standards, users can get motion sickness, latency, or lose the visual quality of experience when switching. These and other tactics are discussed in the following stances in an attempt to put together the best practices for achieving a uniform cross-platform experience. However, cloud-based solutions and AI-based optimization are becoming the new reasonable approaches to close the gap between high-end and standalone VR systems. When developers design VR experiences together in a single piece, it is possible to ensure that the experiences can quickly scale and remain visually and interactively identical and immersive cross-platform. Overall, standardization initiatives and existing technological developments will help to keep VR relatively universal in the sense that irrespective of the used hardware, it will remain fun, intuitive, and comprehensible. The fact that there are no defined rules in the creation and development of VR means that for the future to be more immersed, there has to be the same standard across the platforms.

Keywords: Virtual Reality (VR), Cross-Platform Compatibility, User Experience (UX), Performance Optimization, Standardization, Immersive Technology

1. Introduction

Having started several years ago as an innovative apparatus, Virtual Reality (VR) has recently become common and is widely used in gaming, education, the health sector, and many more. This fast development has created a complex VR environment with various VR systems. It interfaces with varied characteristics in terms of the facilities they present. However, as the VR industry continues to grow, there is the issue of platforms having different hardware, control schemes/inputs, and rendering quality, which are not alike [4, 10].

These differences in systems ranging from more advanced, such as Oculus Quest and HTC Vive, to less elaborate, such as the Google Cardboard, may lead to dissimilar performances partly in the interaction level. These variations are equally challenging to manage in terms of consistency of perception between platforms because users may experience differences in the perceived quality of the visual display, timing of data updates, and control inputs depending on the device they are using [12, 13]. This fragmentation complicates the otherwise smooth access to VR and comes at the cost of the sense of immersion that is so crucial for VR. As users request compatibility across multiple operating systems, following best practices in transitioning subjects between different VR systems is crucial. This paper shall focus on promoting VR consistency between the platforms, especially in various design factors, similar performance in various hardware, and a more user-oriented approach aimed at different VR environments [10, 12]. Considering these factors, we are better placed to develop the right approach to ensure a more integrated and user-centric Virtual reality experience in the global market.

2. Literature review

With the sustained development of Virtual Reality (VR), the evolved product has expanded into several categories of platforms, hardware, and applications. On the one hand, VR covers many possibilities concerning the kind of experience users are exposed to; on the other hand, the variety of HMDs causes a number of problems with regard to homogeneous experiences. As more VR ecosystems are being developed, it is crucial to research existing platforms, challenges that occur with becoming multi-platform, and current approaches to addressing the lack of compatibility. This review delves into these factors in detail.

A.Existing VR Platforms & Ecosystems

Several key players, including Oculus (Meta), HTC Vive, and PlayStation VR, dominate the market. These platforms are pale and distinct in their peculiarities in terms of the kind of hardware they come with, their performance, and their graphical user interface, which is apt for various users with varying usability demands.

1) Oculus Rivet:

Oculus Rift, Oculus Quest, and the Oculus Quest 2 are the most popular VR platforms. Oculus Quest is a tether less product that does not rely on a connection to a computer to be operable, for it is portable and convenient to use. However, this is somewhat marginal compared to PC-attached systems such as the Oculus Rift [12]. Among the drawbacks of The Quest, a lamentable processing power that lessens the graphical quality and speed while drawing the scene could be felt notably in the immersive aspect, likely to be lesser than that of HTC Vive and PlayStation VR.

2) HTC Vive:

HTC Vive has been designed as a premium VR product. The Vive supports external tracking with base stations and has highly accurate movement tracking. Vive systems generally provide a higher graphical quality of the image, resolution, and a higher degree of spatial interaction that can be useful in professional and immersive applications. However, Vive needs significant equipment, including a strong computer and an area where the tracking devices can be placed. As a result, it lacks transportation and portability compared to portable units like the Oculus Quest [10].

3) PlayStation VR:

PlayStation VR supports console gamers and is compatible with PlayStation 4 and PlayStation 5. Based on the characteristics of the console, more optimizations are being made on this platform. However, PS

VR is an average platform in terms of opportunities and offers much fewer, for example, a lower number of pixels or tracking methods than the claimed HTC Vive [10]. In addition, access to PlayStation consoles is crucial, and because of this, the ecosystem's growth comprises hardware compatibility.

The two sets of platforms have unique features regarding the type of hardware and software, which creates several issues regarding the standardization of VR. Discrepancies due to means of graphical processing, rates of frames per second, relative areas of view, and protocols of motion tracking, specifically optical and electromagnetic tracking, are also profound. For instance, the HTC Vive can provide higher frame rates and highly accurate motion tracking, increasing immersion, but not in all systems with low computational power [10]. For these reasons, cross-platform VR is a challenge since consistency has to be sought without compromising efficiency.

B. User Experience Challenges in Multi-Platform VR

This paper clearly shows that the UX in VR is highly contingent on the platform's performance. This is because different VR devices are characterized by differences in tracking, rendering, and interaction mechanisms, and the user may shift between varied means on different hardware systems.

1) Graphics and Performance:

The major issue that can be easily distinguishable in VR UX is the difference in graphics and performance. Pro governors like HTC Vive and Oculus Rift frequently have better clarity, faster frame rates, and intricate graphics pipelines, making virtual realities smooth and detailed. However, in devices such as standalone Oculus Quest, the level of visually perceived quality may seem similar but is technically challenging to achieve [12]. The above dissimilarities in graphics result in a break in immersion to the consumers, based on their expectations of receiving similar graphical functions of the game no matter the device on which it is being played.

2) Latency and Tracking:

Haptic content may also have another parameter of latency, which differs from one VR system to another. The latency problem that prevents immediate response of the user interface when user input is applied is entirely compromising for VR. Devices that track their movements with an outside source, such as HTC Vive, have a slight advantage in latency reduction compared to mobile or standalone gadgets that may not be capable of providing real-time feedback [13]. Also, tracking precision, especially in headset sound and hand controller, notably depends on performance. For example, PlayStation VR depends on a special camera called the PlayStation Camera, and the accuracy of this camera is lower than that of base stations used in HTC Vive. However, Oculus Quest uses inside-out tracking, which may be slightly less accurate than the outside-in approach in some environments [4].

3) Input Devices:

There are several input devices, such as hand controllers, eye tracking, and even voice control, which can make a signal difference to the whole impression. While the latest systems, like HTC Vive Pro Eye, include eye-tracking technology, some systems use only basic hand controllers, which hinders natural interactions in a virtual environment. Another issue that the compromised input methods policy causes is an inconsistency that is brought about by the fact that one is allowed to input data into the system in a variety of methods that are different from the regular and sophisticated methods of inputting data into developed systems, which end up frustrating the users.

4) Haptics and Feedback:

Haptic feedback is critical in a VR environment because it makes the user feel like he/she is in the environment. However, haptic feedback per se is not unique and can be applied in several forms. Some stations like HTC Vive and PlayStation VR have developed controllers that bring about haptic feedback, meaning that users can feel some objects when they are virtually controlling or interacting with them. However, other VR systems, such as the Oculus Quest, may have less complex feedback systems, reducing the user's feeling of presence [4]. In this way, the variation in haptic performance depicted above is always tiny and unnoticeable but significantly contributes to perceiving the unity of the VR space.

A. Current Approaches to Cross-Platform Compatibility

Several proposals have been developed to ensure compatibility between VR platforms and make the experience as smooth as possible, given the fragmentation of VR platforms.

1) Game Engines (Unity and Unreal Engine):

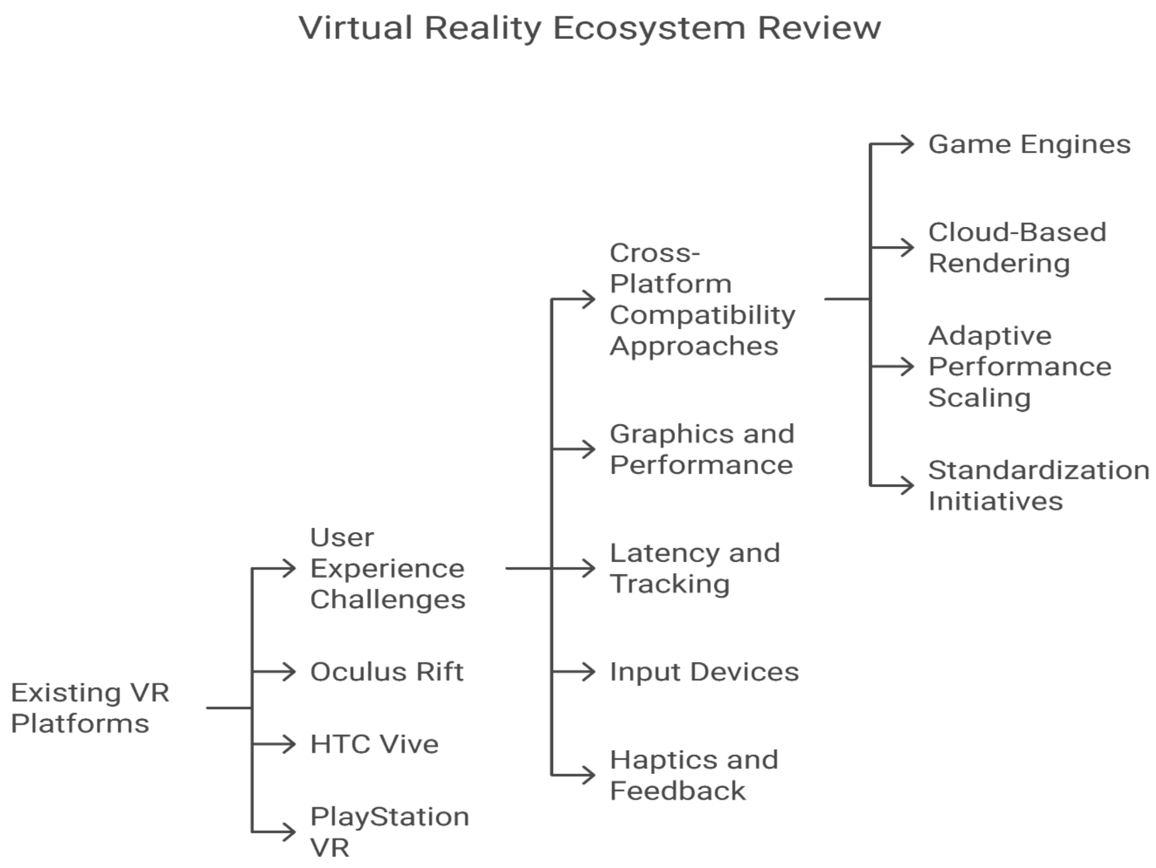
Unity and Unreal Engine are some of the most important tools for VR developers as they help build VR content compatible with various platforms. Such a capacity ensures that VR content can be developed once and optimized for delivery across various platforms to meet targeted user experiences [12]. Unity and Unreal Engine support the most available VR platforms, such as Oculus, HTC Vive, and PlayStation VR. They offer tools for optimizing the game and its performance on other platforms.

2) Cloud-Based Rendering:

There are several solutions to use three-dimensional communication in standalone devices when hardware imposes certain limitations; one is cloud-based rendering. Cloud rendering distributes workload to remote sophisticated servers, benefiting handicapped machines since they can afford enhanced graphics even with high latencies. This makes it possible for a Virtual Reality program to be built to run on all platforms and powered by the devices owned by the user interacting with the Virtual Reality game/program [10]. It can popularize VR and provide those who want to create top-quality VR with the adequately developed attainable on various devices.

3) Adaptive Performance Scaling:

Adaptive Performance scaling is a feature whereby the VR content adapts the graphical requirements according to the hardware's abilities. This technique allows changing some rendering parameters or how complex the graphics are rendered to guarantee a higher frame rate on low-end platforms and keep the quality on high-end ones [12]. This is useful in bringing down the lag between devices and making sure that the VR remains very interactive across devices.



4) Standardization Initiatives:

Standardization has an important role to play so that the VR content can be delivered and viewed on different platforms. OpenXR, which the Khronos group has created, and the proposed WebXR are approaches to defining a single layer of interfaces to serve both the hardware and the software of the VR systems. One such framework is OpenXR, a use case consisting of a cross-platform API, which enables applications to be built in VR across various hardware without the need to redeploy entire lines of code repeatedly. These initiatives alleviate some of the fragmentation issues in the VR ecosystem and make them less incompatible [13]. To sum up, the increasing number of VR platforms creates difficulties in achieving a coherent user experience. Thus, game engines, cloud rendering, scalar approaches, and standardization actions seem to be the solutions. These methods also assist in closing these gaps and advancing the field of VR to become
more open and comfortable with many different hardware types. Nonetheless, there are still many concerns to be addressed in order to enhance these works so that they are successfully cross-platform.

3. Future work

The advancements in VR assets show the opportunity for both superior and inferior assets to change further or enhance the continuation of various VR platform interfaces. Thus, as long as Virtual Reality expands, facing the performance problem and the problem of interaction between different platforms will be vital for bringing a true VR experience to people around the globe. The following are some of the economically oriented potentials that are already emerging in the VR horizon, which can help in the achievement of the above-mentioned goals.

A. Advancements in Hardware and Software

Thus, with further developments in the hardware sphere, the difference between VR platforms will be nonexistent. Future VR systems could be more capable of accommodating better processors, enhanced graphics cards, and seamless tracking with enhanced stability across different inferior devices. For example, future VR headsets could have eye-tracking technology combined with adjustable lenses; the next generation of devices does not need higher computational power to produce higher resolution and frame rates [4]. More so, there can be the introduction of better techniques, such as rendering in engines from VR, which could enable better optimization across platforms, and thus, high graphical devices need not strain themselves when executing operations that highly powered ones can perform without straining [12]. Further enhancements to such devices as the Oculus Quest-like devices may help reduce the difference between PC-dependent devices and relatively affordable options.

B. AI-Driven Optimization Techniques

Concerning AI, there are possibilities for enhancing the rendering, resources, and performance scaling in real-time in various VR content. AI can also be developed to tailor how a device performs the rendering based on a device's processing capacity to achieve the best graphical quality that would not slow down a device. For instance, regarding human factors, AI-recruited methods could relate the intricacy of the ecological niche to the supply of capital [12]. Also, it could eliminate or lessen the latency and the effects of delay in a user's movements and actions by anticipating them and adjusting accordingly to allow for more fluid gameplay. This adaptive optimization could help to guarantee that the quality of the Virtual Reality interface is good at all platforms that will be used by the users.

C. The Role of 5G and Cloud Computing

As a result, cloud-based VR rendering and processing can be brought out with the help of high bandwidth and less latency of 5G networks. This will also enable low-end devices to handle high-quality VR image graphics since they will use low-cost Oculus graphics. Depending on the near future, cloud computing in synergy with 5G will also become crucial to ensure fans experience constant and high-quality VR content during which detailed graphical calculations are made in the cloud. At the same time, the user receives low-latency feedback [16, 19]. This will allow viewers to get quality Virtual Reality experiences on their smartphones and low-end headsets without compromising the rendering quality and accuracy of tracking from high-end headsets.

D. Broader Adoption of Cross-Platform Development Frameworks

Regularly developing and deploying the framework for the cross-platform would enhance the convergence of several platforms in VR. Platforms such as OpenXR and WebXR vendors are already delivering a single set of APIs that can be used to create applications that support different VR hardware. As for future work in this area, further refining these frameworks to the newest advancements in hardware will be considered, and creating an application compatible with most VR systems will be easier. A better focus on cooperation between industries to establish a single set of standards in terms of protocols and VR interfaces will contribute to a faster advancement of standard interfaces and solutions for VRs and other related topics, hence the integration of the fields. Their incorporation across the industry will likely expand the application of these frameworks, enhance the development process, and make it easy for many developers to create quality VR content that can run on several platforms [4, 14].

Finally, the future of cross-platform VR consistency appears to be relatively buoyant, considering features such as the future development of hardware, effective functioning of AI, and implying of 5G and cloud computing, as well as the development of cross-platform development frameworks.

4. Acknowledgements

I want to thank everyone who helped me with my research and this paper. The authors would like to thank researchers of virtual reality technologies, consistency across platforms, and related fields for their invaluable contribution. However, I also would like to thank providers who contributed to the further development of VR and funding of the research connected with it, such as the providers who create standards, for example, OpenXR or WebXR. They have successfully pioneered various cross-platform VR ventures in society and other advanced ways of running VR systems. I must also thank my fellow students and colleagues for their administrative support during this work.

5. Discussion

While recent approaches to guarantee smooth inter-platform compatibility in VR have demonstrated some promising results, some essential characteristics of inter-platform compatibility still need more enhancement. However, through Unity and Unreal, some listed below, there is a shift towards a more consolidated environment in creating VR content across platforms rather than disparate ones. There are significant differences in the actual hardware capabilities of devices: they differ in the processing power, range, and speed of rendering or tracking methods. The current high-end devices, including HTC Vive Pro and PlayStation VR2, come with strong processors and accurate tracking abilities that offer high visual realism and interactivity. Therefore, less expensive implementations like mobile VR headsets may have less graphics and tracking precision than higher-end devices, and this causes variations in user experiences [5, 10].

In addition, some general solutions are associated with cloud-based rendering and the ability to adjust performance depending on the current hardware. However, it is also worth mentioning that they are not without drawbacks either. Cloud rendering shifts the heavy computations to other powerful servers in the cloud. The idea of less computational power on the client side enables the delivery of high-quality VR. However, this situation brings new problems of network dependency, latency, and dependency on stable and fast connections to the internet. Specifically, some of these solutions may become slow and hazy and cause interruptions, hence not being immersive in environments where the network connection changes abruptly or there is enormous traffic [9]. These issues will remain significant with the continued development of VR because of the necessity to achieve a high quality across a range of VR devices.

The issues of performance versus accessibility are critical in designing for multiple platforms, such as VR. On the one hand, developers are often oriented to higher graphics quality and more effective-performing games to offer engaging visuals to the consumer. However, this is achieved at the expense of reduced chances of VR content access to clients with low-end PCs, low-end graphics cards, or slow internet connections. Players using mobile VR headsets or weak PCs will most likely suffer from slow loading, low FPS, and low-quality graphics, significantly affecting the gaming experience. These compromises reflect a paradigm that has been an issue of concern up to date in attempts to optimize the visualization results between the device's display constraints and accuracy [14, 19].

However, to reach the goal of developing an inclusive VR environment, further attention should be paid to the specialized technical obstacles. Developers need to think about the users with robust systems on the maximized high end on the one hand and the users who have relatively lower configurations on the other hand. Occasionally, weaknesses can enable developers to downscale the screen quality or decrease the complexity of the created environments to maintain excellent functionality on lower-end hardware components. However, these compromises might downgrade the idea of getting absorbed in the virtual reality world. Thus, the approach to developing highly polished product designs that are universally accessible can only be as careful and measured as it is ambitious. To overcome these issues, there are various methods, such as dynamic resolution scaling, by which the graphical quality changes depending on the device's capabilities to ensure a better experience [12].

6. Conclusion

Thus, one of the main issues that need to be addressed while developing VR experiences across multiple platforms is the variability of the hardware devices, input/output devices, and rendering techniques between platforms. The differences are prosaic and lead to issues such as graphics, tracking, and latency variations that affect the user experience. Dealing with these issues is possible using strategies, including game engines like Unity/Unreal for multi-platform functionality, covering investments in cloud rendering, and following standardization platforms like OpenXR/WebXR. Although these solutions provide definite directions for getting connected, they have some drawbacks and need constant improvement due to the development of VR technologies.

In this respect, a message from the heads of each industry at both micro and macro levels is imperative to encourage collectiveness. Thus, the future of VR as an ordinary tool requires a consensus among the market participants, which consists of hardware makers, software creators, and platform owners. While industry initiatives like the OpenXR are helping developers leave behind the complexities involved in creating different applications for every platform, they have to be refined further to eliminate the problem altogether. Only in this way can the VR ecosystem become united and more accessible, given the unity that it requires.

Overall, improvements in hardware technology, inventive AI algorithm techniques, and a cross-platform toolkit will be achieved soon to bring more immersive multiplayer VR across multiple platforms. The technologies of the future, for instance, 5G and cloud computing, present a new way through which it is possible to go past these challenges and create better VR interfaces that could be enjoyed across a broad range of devices. As the industry is embedded and connected, the aspiration of a VR environment free from barriers and integrated full-breed virtual space, which is seamless and interactive with a broad audience, will become even more tangible. There is no doubt that the future of VR is promising, and unending opportunities for its application in industries and personal uses are manifested.

References

1. Abubakari, M. S., & Hungilo, G. (2021). Evaluating an e-Learning platform at graduate school based on user experience evaluation technique. Journal of Physics: Conference Series, 1737(1), 012019. IOP Publishing. https://doi.org/10.1088/1742-6596/1737/1/012019
2. Ajith, N. T., P, S., & Mathew, L. S. (2025). Experience Matters: Exploring the Impact of User Experience on Stickiness and Loyalty in OTT Platforms. International Journal of Human–Computer Interaction, 1-15.
3. Joshi, A., Scheinost, D., Okuda, H., Belhachemi, D., Murphy, I., Staib, L. H., & Papademetris, X. (2011). Unified framework for development, deployment and robust testing of neuroimaging algorithms. Neuroinformatics, 9, 69-84. https://doi.org/10.1007/s12021-010-9094-3
4. Majrashi, K., Hamilton, M., & Uitdenbogerd, A. L. (2016, July). Cross-platform cross-cultural user experience. In Proceedings of the 30th International BCS Human Computer Interaction Conference. BCS Learning & Development.
5. Majrashi, K., Hamilton, M., Uitdenbogerd, A. L., & Al-Megren, S. (2020). Cross-platform usability model evaluation. Multimodal Technologies and Interaction, 4(4), 80. https://doi.org/10.3390/mti4040080
6. Marcus, A. (Ed.). (2014). Design, User Experience, and Usability: User Experience Design for Diverse Interaction Platforms and Environments (Vol. 8518). Springer. https://doi.org/10.1007/978-3-319-07626-3
7. Perlman, G. (2000, November). The FirstSearch user interface architecture: Universal access for any user, in many languages, on any platform. In Proceedings on the 2000 conference on Universal Usability (pp. 1-8).
8. Punchoojit, L., & Hongwarittorrn, N. (2017). Usability studies on mobile user interface design patterns: a systematic literature review. Advances in Human-Computer Interaction, 2017(1), 6787504. https://doi.org/10.1155/2017/6787504
9. Putra, M. D. W., & Hermawan, P. (2024). Optimizing User Experience: A Data-Driven Approach to Enhancing B2B Invoicing Efficiency across Multiple Platforms PT Pakar Digital Global. International Journal of Current Science Research and Review, 7(6), 4020-4037.
10. Schlueter, J., Baiotto, H., Hoover, M., Kalivarapu, V., Evans, G., & Winer, E. (2017, May). Best practices for cross-platform virtual reality development. In Degraded environments: sensing, processing, and display 2017 (Vol. 10197, pp. 51-63). SPIE. https://doi.org/10.1117/12.2262753
11. Schuurman, N., Leight, M., & Berube, M. (2008). A Web-based graphical user interface for evidence-based decision making for health care allocations in rural areas. International Journal of Health Geographics, 7, 1-12. https://doi.org/10.1186/1476-072X-7-49
12. Seffah, A., & Javahery, H. (2004). Multiple user interfaces: cross-platform applications and context-aware interfaces. Multiple user interfaces: Cross-platform applications and context-aware interfaces, 11-26.
13. Seffah, A., Forbrig, P., & Javahery, H. (2004). Multi-devices "Multiple" user interfaces: development models and research opportunities. Journal of Systems and Software, 73(2), 287-300. https://doi.org/10.1016/j.jss.2003.10.006

14. Segun-Falade, O. D., Osundare, O. S., Kedi, W. E., Okeleke, P. A., Ijomah, T. I., & Abdul-Azeez, O. Y. (2024). Developing cross-platform software applications to enhance compatibility across devices and systems. Computer Science & IT Research Journal, 5(8), 2040-2061.
15. Shin, D. (2015). Beyond user experience of cloud service: Implication for value sensitive approach. Telematics and Informatics, 32(1), 33-44. https://doi.org/10.1016/j.tele.2014.02.002
16. Shin, D. H., & Biocca, F. (2017). Explicating user behavior toward multi-screen adoption and diffusion: User experience in the multi-screen media ecology. Internet Research, 27(2), 338-361. https://doi.org/10.1108/IntR-05-2016-0129
17. Venkova, J., & Nkpoikanna, E. (2024). Optimizing User Experience Across Platforms: A Study on Enhancing music-streaming Applications' Cross-device Unification.
18. Yang, C., & Singh, S. S. B. (2024). User Experience in Information System Platforms: A Study on Learning Styles and Academic Challenges. Journal of Internet Services and Information Security, 14(4), 209-223.
19. Zidianakis, E., Partarakis, N., Ntoa, S., Dimopoulos, A., Kopidaki, S., Ntagianta, A., ... & Stephanidis, C. (2021). The invisible museum: A user-centric platform for creating virtual 3D exhibitions with VR support. Electronics, 10(3), 363. https://doi.org/10.3390/electronics10030363
20. Zhou, Q., Wang, S., & Wang, J. (2025). Exploring User Experience in Virtual Industrial Heritage Platforms: Impact of Cultural Identity, Functional Clarity, Scene Interactivity, and Narrative Quality. Buildings, 15(2), 253.