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Unified Metaverse Creation: A Model Design for Converging Services in Metaverse Development Process

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Abstract: The online service market has seen increased integration and activation driven by manufacturing efficiency and automation, further accelerated by the COVID-19 pandemic, leading to a growing demand for Metaverse technology and applications. However, developing Metaverse applications using diverse methods presents significant cost and time constraints for developers and businesses. In particular, the development of integrated application services based on the metaverse is facing an increase in development process complexity, which can lead to a significant rise in development costs and time. This study proposed an optimized design approach for Metaverse application development models. The concept of a 'Metaverse convergence service' refers to a pioneering service that seamlessly merges conventional application-based information services with cutting-edge Metaverse technology and tools. The 'Unified Metaverse Creation' model addresses this issue, providing Metaverse developers with support for working convergence processes in a consistent environment and enhancing service quality. The challenges associated with developing Metaverse convergence services were investigated in the research, and essential assessment criteria for the development system were outlined. Therefore, this study aims to propose an optimized design methodology for the Metaverse integration application development process model, analyze key technological issues, suggest strategies for successful development, and provide an evaluation framework for Metaverse integration systems.

Keywords: Augmented Reality, Development model, Metaverse, Process design, Virtual Reality

1. Introduction

Along with the efficiency and automation of 21st century manufacturing, there has been a continuous enhancement in integrating and activating the online service market. Particularly, there has been a rapid increase in demand and convergence requirements for Metaverse technology, Metaverse application services, and digital virtualization services, along with the latest VR/AR technologies that support the spread of non-face-to-face online digital services due to the COVID-19 pandemic[1][2].

The Metaverse market is projected to grow from 50 trillion won in 2019 to the 1,700 trillion won range by 2030, according to PricewaterhouseCoopers (PwC), a global consulting report[3][4]. It is anticipated that through integrating the Metaverse with industries such as online education, healthcare, distribution, and fashion, the market scope of each industry will expand, and major industries will interact based on Metaverse platforms. Tim Sweeney, CEO of Epic Games, predicts that in the future, humanity will spend time engaging in work or shopping through the Metaverse as an intermediary[5]. Therefore, the Metaverse is expected to strengthen the converging industrial revolution, pursuing diverse integration of future human civilization and technology, based on the fourth industrial revolution that

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advances digital technology and automation.

Creating a new Metaverse business environment requires two-way communication between suppliers and consumers for the direct transformation of existing products and services into digital convergence business models, including design, manufacturing, distribution, and promotion. According to a recent Morgan Stanley report cited by investment media Balance, the Metaverse is expected to account for approximately 10% of the overall luxury goods market by 2030[6]. Furthermore, it is predicted that the market size of the Metaverse internal convergence product and service market will reach 57 billion dollars (approximately 67.53 trillion won) within a decade. Additionally, the Direct-to-Avatar (D2A), referring to a business model that directly delivers products to digital avatars, market size is expected to increase from 30 billion dollars (approximately 33.8 trillion won) in 2017 to 50 billion dollars (approximately 56.4 trillion won) by 2022, according to Forbes. The revenue related to avatars in Fortnite in 2019 reached 1 billion dollars, and a new cyber avatar business has emerged where consumers go beyond simple ownership and consume to express their identities through micro-moment consumption. Furthermore, establishing commercialization services that integrate online Metaverse item shops, based on the Online Merge with Offline (OMO) business model, which supplies digitally converged items validated by demand online and physical product items offline, is required. Additionally, by providing usage rights in heterogeneous Metaverse platforms through blockchain-based Non-Fungible Tokens (NFTs), creating new revenue models in the digital convergence service market is expected when purchasing digitally converged products[7]. The NFTs represent unique and non-interchangeable digital assets for each token.

Metaverse application developers and suppliers are developing various and differentiated application services through different development methods. This reality demonstrates a chaotic situation and imposes excessive development costs and time constraints on new developers or businesses. Therefore, this study primarily focused on presenting a design approach for a Metaverse application development model to improve the time or cost loss incurred during the implementation of Metaverse applications[8]. The Metaverse convergence service is a pioneering service that seamlessly merges conventional application-based information services with cutting-edge Metaverse technology and tools. This study proposes a process model for the development of Metaverse convergence services, detailing key issues related to Metaverse hardware, software, and services. Additionally, it presents major performance evaluation factors for Metaverse convergence systems.

This paper is structured as follows: Chapter 2 describes the status of Metaverse applications and services through literature review. Chapter 3 outlines the design approach for the Metaverse convergence application development process. Chapter 4 analyzes the main issues and challenges of the Metaverse convergence process model. Finally, Chapter 5 concludes the study and presents future research directions.

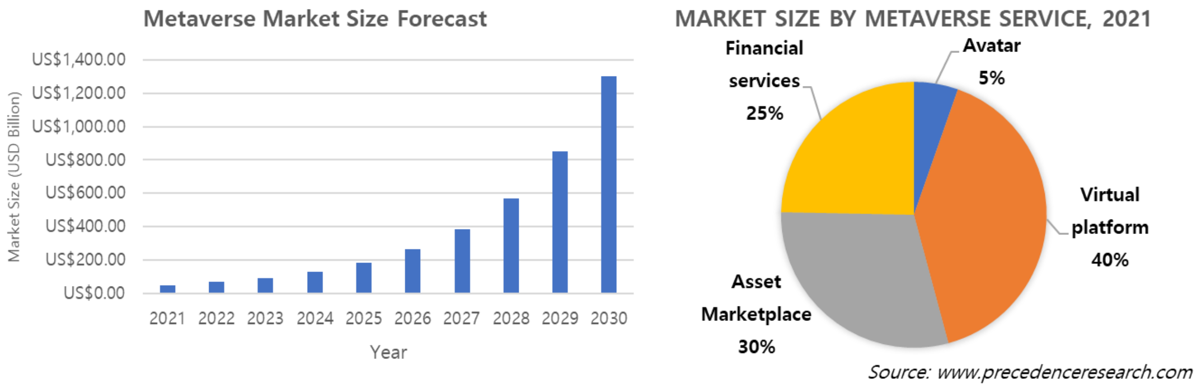
2. Literature Review

2.1 Metaverse Applications and Services Market

The global Metaverse applications and services market experienced substantial growth, driven by the success of Roblox during the COVID-19 pandemic. Key players like Meta's Horizon and The Sandbox are making significant investments to establish dominance. Microsoft also entered the virtual office space in 2021 with 'Mesh for Teams,' aimed at corporate environments[9].

According to a report from Precedence Research [Fig. 1], it is projected to grow at an average annual rate of 44.5% by March 2023. The report indicates that the metaverse market size is set to rise from \$51.69 billion (67 trillion Korean won) in 2021 to \$68.49 billion (89 trillion Korean won) in 2022, with a forecasted value of approximately \$1.3 trillion (1,695 trillion Korean won) by 2030. In 2021, the metaverse services market size can be segmented as follows: Avatar services (\$2.78 billion), Virtual

Platforms ($20.9 billion), Asset Marketplaces ($15.25 billion), and Financial Services ($12.76 billion) [7].



(a) Metaverse Market Volume Forecast (b) Market Size by Metaverse Service

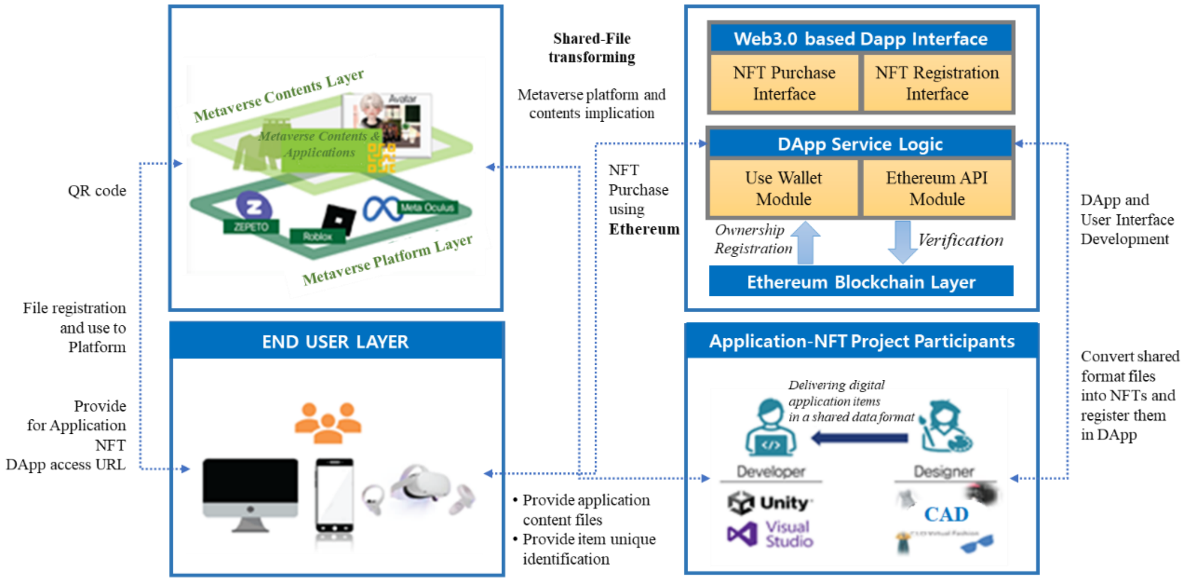
[Fig. 1] Forecast of Metaverse Market Growth and Prediction of Key Converged Application Technology Sectors

Here are examples of leading Metaverse service platforms in the global market: First, Roblox is an online gaming platform that allows users to create and enjoy games developed by others. It can also serve as a communication hub within the Metaverse, facilitating user interactions through features like in-game chat[10]. Second, Horizon, launched by Meta, offers immersive communication in virtual spaces. It combines virtual reality avatars, application software, and communication tools to create a virtual world platform. Last, The Sandbox is a community-centric platform that empowers creators to generate revenue through voxel assets and blockchain-based gaming experiences. The Sandbox introduces a new era of gaming with NFTs, enabling users to design their games. It includes VoxEdit for crafting game items and characters, a marketplace for direct item trading, and a game maker for creating unique gaming experiences.

In the domestic Metaverse platform market, Zepeto is expanding its presence overseas, while Ifland is actively pursuing international growth[11]. SK Telecom has entered strategic cooperation and equity investment agreements with Morph Interactive, a specialist in 3D graphics platforms. Metaverse company Carribeus announced a Series A investment of 3.1 billion won. Here are examples of domestic Metaverse platform leaders: First is Zepeto, operated by Naver JET, a prominent domestic Metaverse platform leveraging augmented reality (AR), virtual reality (VR), and lifelogging technologies. It generates 3D avatars based on the user's appearance and integrates them into actual photos or virtual backgrounds using AR technology[11]. Second is Ifland, a novel Metaverse service platform developed by enhancing SK Telecom's existing service, Jump VR. It prioritizes ultra-low latency virtual reality applications and elevates the realism of the Metaverse ecosystem through Jump Studio.

2.2 Metaverse Convergence Service Technology Landscape

Key Metaverse technologies and major convergence elements encompass development engines and tools, operating systems, display and user interface convergence technologies, and convergence NFT technologies as depicted in [Fig. 2].



[Fig. 2] Metaverse Convergence Commercialization and Convergence NFT Services

Development engines and tools are essential for Metaverse app and service creation, including robust game engines like Unity and Unreal Engine, along with 3D design software. They deliver high-quality graphics and interactive features, enabling realistic virtual experiences.

The Metaverse's operating system includes user space and location recognition algorithms, virtual scenario customization algorithms, real-time network transmission, GPU servers, edge computing, and more. These technologies reduce costs and processing times, enable dynamic avatar creation, enhance accessibility across languages, and expand the virtual world autonomously.

Display and user interface convergence technologies in the Metaverse amplify immersion and sensory interactions via hardware and software advances, encompassing VR, AR, mixed reality (MR), and related technologies.

Metaverse-based convergence content technologies support services in entertainment, culture, broadcasting, education, healthcare, and other domains by inducing human senses and cognition, expanding real-like experiences and emotions.

Convergence NFT technology, a vital Metaverse component, enables permanent storage of ownership and transaction records for digital files on the Metaverse-linked blockchain, facilitating digital asset monetization.

2.3 Challenges and Status of Metaverse Convergence Development

Metaverse convergence application design entails several challenges [8][9][12]. To address these challenges, developers must first integrate diverse technology stacks and become proficient in multiple technologies. Ensuring compatibility between these stacks during integration requires thoughtful consideration and prototyping. Second, the Metaverse should work on various devices, including PCs, mobile devices, VR, AR, and others. It requires compatibility and optimization for various devices. Therefore, designing UI/UX considering different devices and developing optimized versions for each device is essential. Third, the Metaverse's diverse user interactions pose security risks. Addressing these concerns requires implementing preventive measures in the design and architecture, such as utilizing security technologies to safeguard user data and personal information, and improving user authentication and authorization management[12]. Fourth, managing extensive data traffic in the Metaverse is vital for service quality. This involves securing server and network infrastructure, implementing performance management and monitoring, analyzing user behavior, collecting feedback, and ongoing service improvement. Fifth, offering diverse content in the Metaverse for a wide range of user experiences is essential[13]. This requires collaboration with experts possessing the necessary technologies and expertise for content creation. Additionally, building appropriate content search and recommendation systems to facilitate easy discovery of desired content by users is important. Finally, delivering tailored user experiences is paramount for enhancing user satisfaction. This entails understanding user requirements and designing user experiences accordingly[14].

By considering these issues and designing the Metaverse convergence development process, it is possible to provide more successful Metaverse services.

3. Methodology of Metaverse Convergence Application Development

This section aims to design a development process for constructing a Metaverse convergence service development model using traditional software system development methods.

3.1 Metaverse Convergence Development Process

Metaverse convergence application development is a complex process involving the integration of various technologies, such as virtual reality, augmented reality, blockchain, and artificial intelligence, to create a seamless and immersive experience for users. The design process consists of six stages, including:

- (1) Conceptualization: The first stage involves defining the idea and vision for the Metaverse convergence application. This includes identifying the target users, the purpose of the application, and the desired features to be included.
- (2) Research and Analysis: This stage includes conducting thorough research on the market, user needs, and available technologies. This is also the stage of identifying gaps in the market space, potential competitors, and choosing the appropriate technology stack for the application.
- (3) Design and Prototyping: Developing the application's design by creating wireframes, designing the user interface, and generating prototypes are done in this stage. The design should consider both user requirements, preferences, and technical constraints.
- (4) Development: This stage focuses on utilizing tools like Unity and Unreal Engine to develop the Metaverse convergence application, enabling compatibility with VR environments. Interfaces are implemented to support VR interaction and ensure the application can be deployed and run smoothly.
- (5) Integration and Testing: In this stage, integrating the different technologies and conducting comprehensive testing takes place to ensure the functionality, performance, and usability of the application. Module-level unit testing, followed by integration testing, are also performed here to enhance testing efficiency and reliability.
- (6) Launch and Maintenance: After thorough testing and refinement, launching the application in the market comes next. Continuous maintenance and updates are essential to meet user needs and remain competitive.

During designing and prototyping, effective collaboration among designers, developers, and project managers is essential. Promptly addressing any issues or challenges that arise during these stages is vital to avoid project delays. Additionally, it is important to utilize suitable technologies and tools for application development, such as VR, AR, blockchain, and AI.

Key challenges in Metaverse convergence application development include:

The first challenge is creating application-specific content: Employ 3D fusion content modeling for realistic visual designs. Develop digital prototypes for 3D fusion services, allowing users to experience digital fusion applications and products within the Metaverse development platform.

The second challenge is providing the Metaverse transition process for 3D concept design: Develop interfaces and workflows via smart app development on standard platforms. Build VR/AR content development environments using tools like Unity. Create internal interfaces and application content. Register and commercialize the developed App.

The third challenge is supporting the development of Metaverse-compatible application platforms: Creating platforms that are compatible with the Metaverse involves using engines like Unity and Unreal Engine to develop application service platforms. These platforms should feature diverse displays and immersive spaces for digital fusion products, offering unique content services. They should also establish models and standards for digital fusion products suitable for the application platform. Additionally, ensuring compatibility through automatic file conversion, supporting the integration of NFT payment interfaces, and facilitating digital fusion product payments using various transaction systems, including virtual currencies.

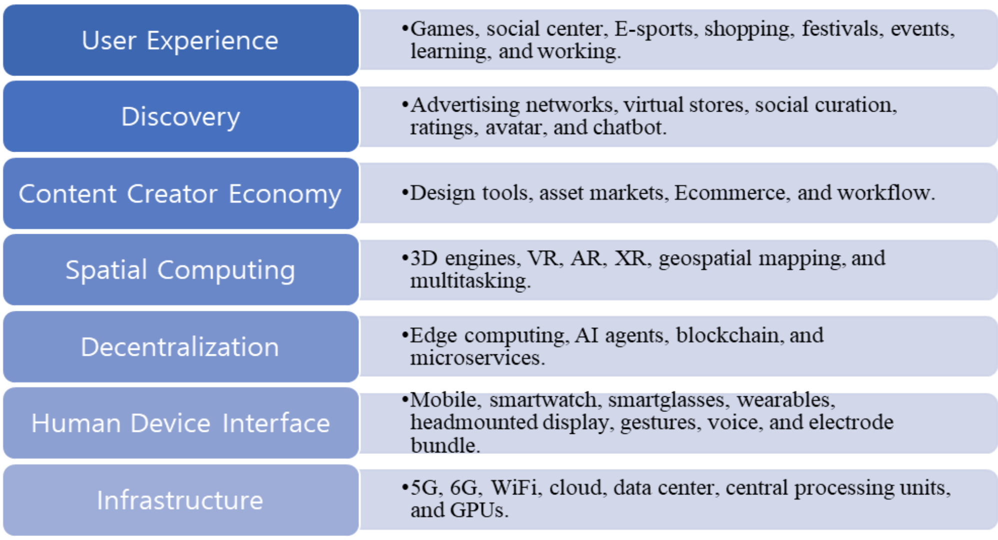
3.2 Metaverse Convergence Application Development Platform

To create a cross-platform support for application development strategy, VR/AR development environments should be built using Unity's extended reality (XR) and VR toolkits for VR/AR development. A conduct of research and development of optimized interaction methods for mobile environments, and a development of Metaverse applications that can run on mobile or PC should be done.

[Fig. 3] illustrates seven layers within the metaverse, each featuring distinct technologies [12][15]. The first layer encompasses diverse user interactions, including content consumption, shopping, NFTs, sports, immersive worlds, games, digital media, and more, all within an experiential framework. In the second layer, information-sharing and marketing platforms facilitate discovery, encompassing both outbound and inbound channels, including community content platforms, search engines, and app stores. The third layer empowers makers and creators with design tools, apps, asset markets, and workflow platforms, facilitating creativity in a Web3 era marked by accessible drag-and-drop application builders. Spatial computing in the fourth layer seamlessly merges real and virtual spaces, eliminating boundaries through 3D engines, AR, VR, XR, and mapping. The fifth layer embodies the metaverse's decentralization ethos, featuring blockchain, smart contracts, open-source platforms, and self-sovereign digital identities. The sixth layer, the 'human device interface,' enhances our physical selves through wearables, neural networks, smart eyewear, VR headsets, and haptics. Finally, the seventh layer represents metaverse infrastructure, comprising data centers, cloud computing, wireless networks, materials, and processing capabilities, providing the technological backbone.

[Fig. 3] depicts the development environment and business platform for Metaverse convergence application illustrates the various components and technologies involved in developing and deploying Metaverse applications. The development environment includes tools such as Unity and Unreal Engine, which are widely used for creating immersive VR and AR experiences. These tools provide a platform for designing and developing Metaverse applications that can be compatible with VR environments. On the other hand, the business platform encompasses the infrastructure and ecosystem that supports the deployment and monetization of Metaverse applications. This realm includes critical elements like content management systems, transaction systems, and payment gateways, fostering user access and interaction with Metaverse applications while offering developers avenues for monetization.

Overall, this figure highlights the importance of a comprehensive development environment and business platform in realizing the potential of Metaverse convergence applications. It displays the integration of technology, content, and business models to create a seamless and immersive Metaverse experience for users.



Source: Blockchain Council (https://www.blockchain-council.org/metaverse/), Sep. 2022

[Fig. 3] Metaverse Convergence Application Development Environment and Business Platform

4. Analysis of Metaverse Convergence Application Issues

This section describes the main system components, technologies, and performance analysis and evaluation metrics for Metaverse convergence applications.

4.1 Analysis of Metaverse Technology Development

Metaverse application development relies on various technologies, including hardware utilization, software application, Metaverse platforms, and service technologies such as VR-based development processes and issue analysis applied in architectural design[16].

4.1.1 Metaverse Device Issues

Metaverse hardware utilization technologies support the development of various software and content for VR and AR environments, such as Oculus Quest2 and Microsoft HoloLens2. Metaverse devices primarily utilize wearable devices, especially headsets (HMD) or glasses, to implement AR and VR experiences[12][16][17].

Advanced hardware manufacturing techniques, network technologies including 5G, and content and display technologies are being actively explored for new technical advancements and service developments in various competitive fields, primarily led by advanced countries.

4.1.2 Metaverse Software Issues

Metaverse software application technologies support digitalizing various business items using digital 3D design tools. These include technologies for implementing maps and content using Unity, smart contract design based on Ethereum network using Dapp, and interface technologies for integrating NFT into Metaverse platforms.

Software for Metaverse applications is led by programming technologies such as Unity and Unreal Engine, as well as proprietary studios like Naver's 'Zepeto' and Meta's 'Horizon'[12]. The three reality technologies, virtual, augmented, and mixed reality, are evolving to provide realism, immersion, and a sense of existence. Multinational companies such as Microsoft, Google, and Amazon are actively researching the convergence and application of virtual, augmented, and mixed reality technologies. The focus of the Metaverse is on enabling interactions between avatars representing people within virtual spaces, allowing interactions between virtual-virtual and virtual-real environments.

4.1.3 Metaverse Platform and Service Issues

Metaverse platform and service technologies support implementing various application services, including digital item creation using 3D design tools, Metaverse content theme mapping, mini-game development, and avatar-based applications[10][11][17].

Leading Metaverse platforms include Microsoft's 'Mesh,' Google's 'Starline,' Facebook's 'Horizon,' Nvidia's 'OmniVerse Enterprise,' and Naver's 'Zepeto'[11][12]. The Metaverse aims to go beyond first-person immersive experiences and enable everyday life and work in virtual spaces with interactions with virtual characters. This shift gains importance, driven by the rising demand for interactive virtual reality environments, particularly in response to the increased need for non-face-to-face experiences due to COVID-19.

These key technologies continue to evolve regarding developers' productivity, developers' and users' convenience, high-quality application services, and industrial application diversity. To enhance developers' productivity, development environments and tools are continuously improving. Notably, engines like Unity and Unreal aspire to optimize Metaverse content and interface development tools for user-friendliness, ultimately reducing development time and effort while bolstering productivity. Initiatives to enrich the scale and quality of open assets, enabling effective content development, are underway. Additionally, explorations encompass.

To enhance developers' and users' convenience for Metaverse application and service development, the following aspects are emphasized. Performance and features of AR and XR devices are utilized to provide users with richer experiences. Developers develop content and interaction features optimized for these devices to enable users to interact more conveniently in a blended environment of reality and virtuality. Furthermore, to improve the quality of Metaverse application services, stability, performance, and user interfaces are optimized. As users expect smooth and reliable experiences, developers must collect user feedback and make improvements accordingly. Developers create various application services tailored to different industries, enabling the maximum utilization of the potential of the Metaverse in areas such as education, entertainment, marketing, communication, and more[18].

4.2 Performance Evaluation Metrics for Metaverse Convergence Systems

Performance analysis and evaluation metrics for Metaverse convergence systems should consider various aspects such as those described in this section. To further enhance the evaluation metrics and analysis methods presented in the paper, additional mathematical models can be incorporated. The key metrics include the following such as [Table 1]:

[Table 1] Metrics for evaluating Metaverse Convergence Systems

Evaluation Criteria	Contents	Units
Network Latency	A critical metric for evaluating network performance and response time, indicating the delay occurring during the transmission and reception of data.	milliseconds (ms)
System Stability	An indicator of how consistently a system operates over a certain period	percentage (%)
Availability	How accessible a system is and is often expressed as a percentage to assess the system's uptime.	percentage (%)
Security and Privacy Protection	Security assessment considers factors such as the number of vulnerabilities, effectiveness of security measures, and threat response capabilities, which can be quantified or graded.	scores or grades

	It assesses how effectively a system safeguards and processes personal information, often expressed as a percentage.	percentage (%)
User Experience	Usability, User Satisfaction, Retention Rate, Engagement Metrics, Net Promoter Score, etc.	user task completion time, error rates, various scores, etc.

4.2.1 Network Bandwidth and Latency

Metaverse convergence applications require real-time processing and transmission of diverse data. Therefore, network bandwidth and latency are crucial evaluation metrics. Establishing a stable network infrastructure is essential to ensure a seamless Metaverse experience. It can employ mathematical models to calculate the network's capacity and estimate the required bandwidth, considering expected data loads, user traffic, and queuing delays within the Metaverse system.

4.2.2 Error Handling and System Stability

Reliable operation of Metaverse convergence systems across many users and diverse environments is paramount. The assessment of system stability encompasses a multifaceted evaluation, considering factors such as fault response, error handling proficiency, and scalability. To attain this stability, it is imperative to establish an efficient system architecture, employ effective monitoring tools, and maintain a robust server infrastructure. The application of mathematical optimization techniques serves as a pivotal means to enhance system architecture and resource allocation, ultimately bolstering system stability and fortifying its resilience against faults.

4.2.3 Availability and Scalability

Metaverse convergence applications must efficiently handle a large number of concurrent users. Therefore, system availability and scalability are crucial evaluation metrics. To accommodate growing user numbers, it is essential to have an architecture that supports both horizontal and vertical scaling, along with effective resource management techniques. Mathematical models, such as load balancing algorithms or resource allocation algorithms, should be employed to optimize system scalability and ensure efficient resource utilization. For instance, 99.9% availability corresponds to approximately 8.76 hours of downtime per year. 'Horizontal scalability' may involve increasing the number of servers, while 'vertical scalability' could refer to upgrading server performance, indicating the system's capacity for expansion.

4.2.4 Security and Privacy Protection

Security and privacy protection are important considerations in Metaverse convergence applications, given their involvement in managing users' personal information. To ensure robust security, the system must incorporate effective authentication and encryption technologies, thereby safeguarding user data. It is imperative to obtain explicit user consent and maintain transparency throughout the data collection and processing phases. For example, when evaluating the security strength and integrity of the Metaverse system, it involves the application of cryptographic algorithms and mathematical encryption models. This ensures that sensitive information within the system is securely stored and transmitted. Additionally, assessing the level of privacy protection when collecting and processing user data can be achieved through the implementation of differential privacy models.

4.2.5 User Experience

The success of Metaverse convergence applications relies heavily on user satisfaction and experience, which are assessed based on the user interface's intuitiveness, responsiveness, and graphical quality. To achieve this, prioritize interfaces that enable easy navigation and ensure optimized graphic performance.

To enhance user satisfaction and usability, human-computer interaction models are utilized to analyze user interactions, cognitive load, and task performance within the Metaverse system.

By considering these performance analysis and evaluation metrics, it is possible to develop and enhance Metaverse convergence application systems. By incorporating these mathematical models, the evaluation metrics and analysis methods presented in the paper can be further strengthened, allowing for more quantitative and rigorous assessment of the Metaverse convergence systems.

5. Conclusions

This study proposed an optimized design methodology based on the Metaverse integration application development process model, analyzed hardware, software, and service issues related to key technological developments, and provided corresponding strategies for successful development. Additionally, it presented major evaluation criteria and assessment content for performance evaluation of the Metaverse integration systems.

Furthermore, the outcomes of this study are anticipated to contribute to generating the following technological, socio-cultural, and economic impacts. Technologically, it shifts analog design methods to digital and Metaverse app development, fostering diverse digital innovations. Socio-culturally, it targets digital industrial design for the modern generation, supports digital life cycles, and bridges virtual and traditional cultures. On the economic front, it envisions expanding the Metaverse market and integrated industry growth, which will lead to increased revenue and the emergence of innovative business models. As a future research direction, advancing development processes and platforms is intended by creating exemplar Metaverse integrated services.

Lastly, when configuring the overall development process and system from an integrated perspective, there can be numerous obstacles in terms of compatibility and interface configuration. Therefore, an appropriate advanced development framework aligned with the proposed development process needs to be provided. Furthermore, additional enhancements and validations might be necessary for system performance improvement and service quality enhancement, focusing on actual implementation cases based on the proposed evaluation criteria.

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