

## A Study on the Development of an Open-Stage Metaverse Specialized Mall Using Motion Recognition Technology

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### [Abstract]

The purpose of his study is to provide a differentiated shopping experience in an open-stage metaverse mall using motion recognition technology. The findings confirmed that motion recognition enhances user immersion and provides a more intuitive shopping experience. Additionally, enhancing seller support functionalities improved the efficiency of virtual store operations. However, the study has limitations. First, the number of participants was small, and large-scale performance testing was insufficient. Second, motion recognition accuracy is affected by environmental factors (e.g., lighting, background), requiring improvements for real-world use. Third, the system is currently platform-dependent (Unity-based), necessitating further research on cross-platform compatibility. Future research should explore motion capture and wearable sensors to improve accuracy, integrate AI-driven personalized services, and enhance virtual store navigation with interactive experiences for continuous innovation in metaverse shopping environments.

▶ **Key words:** Motion Recognition, Metaverse, Metaverse Mall, Open-Stage

### [요 약]

본 연구는 동작인식 기술을 활용하여 오픈스테이지형 메타버스 쇼핑몰에서 차별화된 쇼핑 경험을 제공하는 것을 목표로 하였다. 연구 결과, 동작인식 기술이 사용자 몰입도를 향상시키고 보다 직관적인 쇼핑 경험을 제공할 수 있음을 확인하였다. 또한, 판매자 지원 기능을 강화함으로써 가상 상점 운영의 효율성을 높일 수 있음을 밝혔다. 그러나 연구에는 몇 가지 한계가 있다. 첫째, 실험 참가자의 규모가 제한적이었으며, 대규모 성능 테스트가 부족하였다. 둘째, 동작인식 기술의 정확도는 조명과 배경과 같은 환경적 요인에 영향을 받아 실사용 환경에서 개선이 필요하다. 셋째, 현재 시스템은 특정 플랫폼(예: Unity)에서만 실행 가능하여, 다양한 플랫폼과의 호환성을 고려한 추가 연구가 필요하다. 향후 연구에서는 모션 캡처, 웨어러블 센서 등 다양한 동작인식 기술을 적용하고, AI 기반 맞춤형 서비스를 추가하여 사용자 경험을 극대화해야 한다. 또한, 가상 상점의 탐색 기능을 강화하고 인터랙티브 이벤트 등의 새로운 쇼핑 경험을 도입하여 메타버스 쇼핑 환경의 지속적 혁신을 추구해야 할 것이다.

▶ **주제어:** 동작인식, 메타버스, 메타버스 몰, 오픈스테이지

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## I. Introduction

In recent years, the metaverse has rapidly expanded, fueled by advancements in technologies such as virtual reality (VR), augmented reality (AR), blockchain, and digital twins, positioning itself as a new economic space[1]. The rise of remote environments due to the COVID-19 pandemic has further accelerated the growth of the metaverse market, promoting its adoption across various sectors, including entertainment, education, and commerce.

Existing metaverse platforms primarily focus on avatar-based interactions. However, there is a growing demand for technologies that enhance immersion and realism. In this context, motion recognition technology has gained attention as a key technology that enables more intuitive and natural interactions by reflecting users' actual movements in the metaverse environment[2].

Particularly, open-stage metaverse platforms provide spaces where users can freely exhibit, share, and communicate about their creative works, supporting the formation of new types of communities and economic activities. Integrating motion recognition technology into such platforms would allow users to experience a more vivid and immersive interaction through their avatars, thereby enhancing platform engagement and user satisfaction.

Moreover, combining motion recognition technology with 3D modeling, rendering, and animation generation techniques can maximize the efficiency of the creative process and provide users with a highly immersive experience.

Virtual reality technology presents numerous possibilities in the content production industry. For example, in a virtual studio environment, actors' movements can be captured and applied to virtual characters, enabling the creation of realistic animations.

Additionally, real-time facial expression recognition can be utilized to reflect users'

expressions onto virtual characters, enhancing immersive character performances.

Park(2021)[2] argued that metaverse environments can support creative activities and contribute to the emergence of new markets. Jeon Hee-jae and Dwivedi et al.(2023)[3] proposed features such as virtual try-on simulations, interactive experiences, personalized recommendations, and product information visualization to increase purchase conversion rates in metaverse shopping malls.

This study aims to enhance the efficiency of video production and lower the entry barriers for creators unfamiliar with visual expression by achieving the following objectives:

First, Design and implement a 3D model-based storyboard creation system.

Second, Develop automatic character animation generation technology using facial and motion recognition.

Finally, Evaluate the usability and efficiency of the developed tool and apply it to a metaverse-specialized marketplace, utilizing motion recognition technology within a metaverse environment for film and video storyboard creation.

## II. Research Background

### 1. 3D modeling technology

3D modeling is a technology that represents real-world objects or imaginary subjects in a three-dimensional space. 3D modeling is widely used in various fields, including computer graphics, gaming, animation, and architectural design. Recently, it has also been extensively utilized in the creation of virtual reality(VR) and augmented reality(AR) content[4].

Motion recognition technology detects user movements and interprets them as input for computer systems. It has been widely applied in various fields, including gaming, virtual reality, and

robotic control, and has recently gained attention as a next-generation user interface technology [5].

### 1.1 Integrated Face & Motion Tracking Solution

A dual-device system was developed to capture facial tracking and motion tracking data separately using two smart devices, which are then merged and applied in real-time to a virtual character.

The synchronized input signals are integrated using a custom-designed socket communication system (Socket: a communication endpoint that allows two separate hosts to send and receive data over a network).

### 1.2 Face Tracking Technology

Facial recognition is implemented using the cameras and sensors of smart devices.

The system captures and tracks facial expressions and applies them to 2D or 3D character models.

It utilizes ARCore(Google's SDK for building augmented reality applications) and AR Foundation (a Unity framework that integrates ARKit, ARCore, Magic Leap, and HoloLens functionalities) for facial tracking implementation.

Instead of directly converting face tracking input into a mesh, the data is processed and mapped onto the character's facial rig.

OpenCV (Open Source Computer Vision) is used for 2D image processing, enabling functions such as binarization, noise filtering, pattern recognition, and machine learning.

Key facial features (e.g., mouth, nose, eyes) are tracked, and their movements are linked to the joints of the rigged model in real time.

### 1.3 Motion Tracking Technology

Motion recognition is implemented via smart device cameras and sensors. OpenCV is used to track the positions of the user's hands and feet, based on pre-trained models. The system synchronizes the position and rotational data of the detected limbs.

## 2. Motion recognition technology

Motion recognition technology detects and interprets user movements to serve as input for computer systems. This technology is widely utilized in various fields, including gaming, virtual reality, and robotic control, and has recently gained attention as a user interface technology[5].

In this study, a system is implemented to recognize users' facial expressions and gestures, enabling the automatic generation of animations for 3D characters. The MediaPipe Hands model has emerged as a core component of cross-platform frameworks in the field of pose estimation and is used for hand gesture recognition technology[6].

## 3. Dynamic Motion Recognition and LSTM (Long Short-Term Memory) Model

Human actions manifest in various forms, and among them, recognizing motion, a type of human body movement, is one of the most intriguing research areas. This study builds upon the research of Lee(2013)[1] and utilizes motion interfaces commonly used in immersive content.

As proposed in this study, the MediaPipe Holistic solution is employed to extract landmarks of the face, hands, and upper body. The extracted data is used to calculate essential input features for training, thereby enhancing the accuracy of data learning. Jeon and Kim(2022)[6] previously suggested a solution for addressing texture-related issues through haptic feedback in their study on proposing a metaverse-based online fashion shopping app service.

## 4. Case Studies on the Utilization of Motion Recognition Technology in the Metaverse Environment

In the metaverse environment, motion recognition technology plays a crucial role in controlling users' avatars and enabling interactions with the virtual world [5][7].

Table 1. Applications of Motion Recognition Technology in the Metaverse Environment

Function	Content
Avatar Control	Real-time recognition of users' facial expressions, gestures, and hand movements, enabling realistic avatar control.
Virtual Object Manipulation	Recognition of users' hand movements to interact with virtual objects, such as grabbing, throwing, or moving them.
Virtual Environment Navigation	Detection of users' body movements to navigate virtual environments, zoom in/out on specific locations, and explore spaces.
Game Play	Recognition of users' body movements to control game characters and perform various in-game actions.
Participation in Virtual Meetings	Interpretation of users' gestures to facilitate participation in virtual meetings, such as presenting or asking questions.

### 5. Purchase Conversion Rate in Metaverse Shopping Malls and Motion Recognition Characteristics of High-Involvement Products

Metaverse shopping malls are virtual spaces designed to provide users with an experience similar to real-world shopping through their avatars. These environments help compensate for the shortcomings of online shopping, enhance user immersion, and contribute to increasing purchase conversion rates. Motion recognition technology can be utilized to improve the purchase conversion rates of high-involvement products in metaverse shopping malls through the following features[7][8]:

**Try-On Simulation:** Users can visually confirm how specific clothing items or accessories appear on their avatars, aiding in purchase decisions. Motion recognition technology allows users to change their avatar's pose or view products from different angles, enhancing user satisfaction.

**Interactive Experience:** Providing users with a hands-on experience of interacting with products increases their understanding and stimulates purchase desire. For example, in the case of watches, users can simulate the feeling of wearing them by moving their wrists, or for furniture, they can place and resize items in a virtual space.

**Personalized Recommendations:** Motion recognition technology can be leveraged to

recommend customized products based on users' body shapes, styles, and preferences. 3D scanning technology enables accurate body measurements, allowing the system to suggest well-fitted clothing for the avatar.

**Product Information Visualization:** Detailed product information(e.g., material, color, size) is visually presented using 3D modeling, animation, and textures. This enables users to experience not only the product's design but also its texture, helping them make informed purchasing decisions.



Fig. 1. Transactions in the Metaverse Environment

## III. Research Method

### 1. System Design

We propose a method for designing and implementing an open-stage metaverse specialized mall system utilizing motion recognition technology.

The metaverse shopping mall system designed in this study aims to provide an immersive shopping experience in a virtual environment by reflecting the requirements of both consumers and sellers. To achieve this, we analyzed the requirements and defined the system's key functionalities based on the findings[3].

### 2. Requirements Analysis

From the consumer perspective, we examined shopping motivations, preferred features, and interface design. From the seller perspective, we analyzed product display methods, sales promotion strategies, and customer management functionalities.

Additionally, we studied the operational experiences and pain points of existing online shopping malls to provide an improved user experience[9].

### 3. System Function Definition

The key functionalities of the system implemented in this study are as follows[10][11]:

**Avatar Creation and Customization:** Provides a variety of customization options, allowing users to personalize their avatars.

**Open-Stage Space:** Enables users to set up their own virtual stores and display products. **Product Display and Management:** Allows sellers to register and manage product information. **Motion Recognition-Based Interaction:** Supports gesture and voice command-based avatar control and interaction.

**Community Features:** Includes chat, follow, review, and rating functionalities for user engagement. **Product Purchase and Payment:** Implements a secure payment system supporting various payment methods. **Customer Support:** Provides FAQ and chatbot-based inquiry handling.

**Seller Support:** Offers sales performance analysis and marketing tools to assist sellers in store operations.

### 4. Database Design

**User Information Table:** Stores avatar details, purchase history, and preferred products. **Product Information Table:** Includes product name, price, description, stock, images, and 3D models. **Store Information Table:** Contains store name, description, location, and theme data. **Review Information Table:** Stores review content, ratings, author details, and date of submission. **Payment Information Table:** Manages payment amount, method, and transaction timestamps.

### 5. User Interface Design

The user interface(UI) was designed to ensure intuitive usability of the system. **Visual Design:** Incorporates design elements that complement the

metaverse environment. **Navigation Features:** Provides menus, search functions, and filtering options to help users find products easily.

**Accessibility Considerations:** Includes text size adjustments, color contrast settings, and voice guidance features to enhance accessibility.

### 6. 3D Model Creation

3D models were developed for product display and avatar customization, ensuring a diverse range of styles and high-quality assets to enhance user satisfaction.

### 7. Motion Recognition Engine Integration

Using MediaPipe Hands and Kinect SDK, the system implements facial expression recognition, hand gesture detection, and body movement tracking, enabling intuitive interactions between users and the system.

### 8. System Implementation

#### 8.1 Development Environment Setup

The system was developed using Unity 3D and Unreal Engine, integrating 3D modeling tools (3ds Max, Maya) and a motion recognition engine[12].

#### 8.2 Core Function Implementation

- Avatar creation and customization functionality
- Open-stage space provision
- Product display and management
- Motion recognition-based interaction
- Community features implementation
- Product purchase and payment system
- Customer support functionality
- Seller support tools

#### 8.3 Database Integration

- MySQL was used for system data storage and management.

#### 8.4 Optimization

To optimize system performance, code improvements, resource optimization, and memory management were conducted.

## 9. User Evaluation

### 9.1 Participant Recruitment

A total of 10 users with experience in metaverse platforms and online shopping were recruited for evaluation.

### 9.2 User Scenario Setup

Various scenarios were created to allow participants to experience the system: Avatar creation and customization, Virtual mall exploration and product display experience, Product purchase and payment, Community feature utilization

### 9.3 Evaluation Method

After experiencing the system, users completed a survey assessing satisfaction, ease of use, immersion, and purchase intention. Additionally, in-depth interviews were conducted to analyze user experience and identify areas for improvement.

## 10. Results Analysis

The results of the user evaluation were analyzed to identify strengths and weaknesses of the system.

- Ease of use: Assessed the intuitiveness and usability of the system interface.
- Feature satisfaction: Analyzed the impact of provided functionalities on the shopping experience.
- Immersion: Evaluated the level of user engagement within the metaverse environment.
- Purchase intention: Examined the correlation between user experience and actual purchase conversion rates.
- Technical aspects: Reviewed motion recognition accuracy, system stability, and performance optimization.
- User experience aspects: Evaluated immersion, accessibility, and interface usability.
- Functional aspects: Assessed the usability of content creation, community features, economic system, and reservation functions.

## IV. Conclusion

This study aimed to provide a differentiated shopping experience in an open-stage metaverse specialized mall using motion recognition technology and to derive system improvement strategies based on user evaluations. The findings confirmed that motion recognition technology enhances user immersion and provides a more intuitive shopping experience. Additionally, strengthening seller support functionalities was found to contribute to improving the efficiency of virtual store operations[12].

In the process of developing and evaluating the proposed open-stage metaverse shopping mall system utilizing motion recognition technology, several technical limitations were identified.

First, there are limitations related to the accuracy of motion recognition. The recognition engines used in this study—MediaPipe and Kinect SDK—were found to be sensitive to environmental factors such as lighting, background, and user distance. These factors led to reduced recognition performance, especially in complex gesture scenarios involving fine hand movements or multiple users. For real-world application, it is necessary to enhance recognition robustness by incorporating more advanced pose estimation algorithms and applying data normalization techniques.

Second, the system exhibits platform dependency, which constrains its compatibility and accessibility. As the current implementation is built on Unity, it operates effectively only within Unity-supported environments, thereby limiting deployment across other platforms such as iOS, Android, or WebXR. To ensure broader usability, the system architecture needs to be redesigned for cross-platform support.

Third, there are challenges related to performance optimization. During testing, simultaneous execution of 3D rendering, motion recognition, and interaction features occasionally

resulted in rendering delays and frame drops. This was particularly evident in scenarios involving high-resolution models or multiple concurrent users. Therefore, optimization techniques such as object pooling, Level of Detail (LOD) management, and asynchronous processing should be incorporated to improve runtime efficiency.

Lastly, the system faces limitations in motion data processing and learning accuracy. The LSTM-based gesture recognition model relied on a limited set of input features and training data, which constrained its ability to generalize across diverse user behaviors. Recognition accuracy also varied depending on individual users' body types and gesture styles. Future improvements should include the adoption of adaptive learning models and data augmentation techniques to enhance the generalizability and personalization of motion recognition.

These technical issues must be addressed in future research to ensure the system's practical deployment, scalability, and adaptability to various user environments.

From a practical perspective, open-stage metaverse shopping malls utilizing motion recognition technology have positive impacts on both user experience and seller operations.

Motion-based interfaces offer users a more intuitive and immersive shopping experience, thereby compensating for the limitations of conventional online shopping and enhancing realism. This experience can lead to increased user engagement, longer stay times, and more active product exploration, ultimately contributing to higher purchase conversion rates.

The open-stage metaverse-specialized mall system proposed in this study demonstrates clear technical and functional distinctions compared to existing metaverse-based shopping platforms. Conventional metaverse shopping malls primarily rely on basic input devices such as a mouse and keyboard or provide limited preset-based gesture interactions. Consequently, these platforms often

lack the expressive capability and natural interaction needed to deliver a highly immersive user experience.

In contrast, this study introduces a dual-device-based facial and motion tracking solution that synchronizes data from two smart devices to accurately capture and reflect users' facial expressions and body movements onto avatars in real time.

Specifically, the system integrates MediaPipe-based facial, hand, and body detection models with OpenCV-based image preprocessing techniques, as well as an Inverse Kinematics (IK)-driven automatic animation generation engine. This combination enables a high-precision interface capable of mapping even subtle user gestures and facial movements directly onto a virtual character in a responsive manner.

As a result, users can enjoy a more intuitive and natural shopping experience, where gestures such as hand waves or finger movements can be used to rotate, scale, or manipulate virtual products, thereby moving beyond conventional point-and-click interaction paradigms.

Furthermore, the system supports personalized product recommendations based on the user's body shape data. It also allows users to create and customize their avatars and set up virtual stores within an open-stage environment, thereby fostering a user-centric and creative ecosystem. Unlike traditional systems, which are generally consumer-oriented and offer unidirectional experiences, the proposed platform facilitates participatory interactions and content creation, marking a shift toward an interactive and creator-driven shopping mall paradigm.

However, this study has several limitations.

First, there is the issue of a limited sample size. The number of participants was relatively small, and large-scale performance testing in broader user environments was insufficient.

Second, motion recognition accuracy can be affected by environmental factors such as lighting

and background, requiring technical improvements for practical application.

Third, the system is currently designed to operate only on a specific platform(Unity-based), which calls for further research to enhance compatibility with diverse platforms.

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## REFERENCES

- [1] K. Lee, "Tangible fairy tale using motion recognition based on SVM: Application to tangible fairy tale," *Journal of Korea Contents Association*, Vol. 13, No. 4, pp. 64-72, 2013. DOI: 10.5392/JKCA.2013.13.04.064.
- [2] K. Park, "A study on virtual fashion industry cases of fashion brands through convergence with metaverse," *Journal of Korea Science & Art Convergence Society*, Vol. 39, No. 4, pp. 161-178, 2021. DOI: 10.17548/ksaf.2021.12.30.161.
- [3] Y. K. Dwivedi, L. Hughes, Y. Wang, A. A. Alalwan, S. J. Ahn, J. Balakrishnan, and J. Wirtz, "Metaverse marketing: How the metaverse will shape the future of consumer research and practice," *Psychology & Marketing*, Vol. 40, No. 4, pp. 750-776, 2023. DOI: 10.1002/mar.21767.
- [4] R. Schroeder, "Defining virtual worlds and virtual environments," *Journal for Virtual Worlds Research*, Vol. 1, No. 1, 2008. DOI: 10.4101/jvwr.v1i1.294.
- [5] R. Song, Y. Hong, and N. Kwak, "User interface using hand gesture recognition based on MediaPipe Hands model," *Journal of Multimedia Association*, Vol. 26, No. 2, pp. 103-115, 2023. DOI: 10.9717/JMAS.2023.26.2.103.
- [6] I. Kim and I. Jung, "A study on Korean sign language recognition using deep learning-based OpenPose," *Journal of Digital Contents Association*, Vol. 22, No. 4, pp. 681-687, 2021. DOI: 10.9728/dcs.2021.22.4.681.
- [7] H. Jeon and K. Kim, "Proposal for a metaverse online fashion shopping mall app service - Focused on virtual fitting service," *J. of Digital Contents Association*, Vol. 23, No. 4, pp. 589-601, 2022. DOI: 10.9728/dcs.2022.23.4.589.
- [8] E. Y. Song, G. J. FitzPatrick, K. B. Lee, and E. Griffor, "A methodology for modeling interoperability of smart sensors in smart grids," *IEEE Transactions on Smart Grid*, Vol. 13, No. 1, pp. 555-563, 2021. DOI: 10.1109/TSG.2021.3105880.
- [9] M. Liu and P. Kim, "Analysis of Chinese consumers' intention to participate in Taobao metaverse shopping mall through S-O-R model," *Journal of Business Research*, Vol. 39, No. 1, pp. 105-122, 2024. DOI: 10.1016/j.jbusres.2023.04.012.
- [10] O. Dogadkina, "Metaverse shopping: Retailers' new reality," *VentureBeat*, June 5, 2022. Available: <https://venturebeat.com/datadecisionmakers/metaverse-shopping-retailers-new-reality/> (Accessed: Nov. 5, 2022).
- [11] K. Lee, "Design of a tangible game interface using motion in a virtual space," *Journal of Korea Computer Game Association*, Vol. 24, No. 1, pp. 133-144, 2011. DOI: 10.1109/JKCGA.2011.24.1.133.
- [12] B. Shen, W. Tan, J. Guo, L. Zhao, and P. Qin, "How to promote user purchase in metaverse? A systematic literature review on consumer behavior research and virtual commerce application design," *Applied Sciences*, Vol. 11, No. 23, p. 11087, 2021. DOI: 10.3390/app112311087.

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