ISSN:1738-6764, eISSN:2093-7504

Development of Interactive 3D Media Production Based on Multi-Device Integration

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https://doi.org/10.5392/IJoC.2025.21.4.068

Manuscript Received 24 April 2025; Received 14 October 2025; Accepted 17 October 2025

Abstract: *As the demand for immersive content that facilitates physical interactions with users continues to rise, so does the need for such content. The evolution of web technologies is expected to lead to a surge in 3D content that can be executed directly within web environments, providing a 3D experience across multiple platforms. The increasing availability of 3D content creation tools is likely to empower both professionals and novices to produce content more easily. Given the growing demand for 3D content, the trend towards cross-platform availability, and the simplification of content authoring tools, technologies that enable the production of interactive 3D content through Multi-Device Integration in web contexts are set to become essential. To address this demand, this paper presents an interaction API designed to streamline user interactions within web environments. By utilizing this API, developers can create interactive 3D content across various devices. The Interactive 3D Media Production framework enhances usability, accessibility, and platform independence by integrating diverse interaction modalities and providing plug-ins for other authoring tools.*

Keywords: Interactive 3D Media Production; Multi-Device Integration; Web-Based

1. Introduction

The growing prevalence of digital content has catalyzed the emergence of technologies that blur the boundaries between physical and virtual environments, particularly in the context of video content consumption. There is an increasing interest in immersive three-dimensional (3D) content and related technologies that seek to enhance depth perception and user engagement. These immersive 3D experiences are driving innovation across various sectors, including healthcare, entertainment, design, and education, thereby improving visual engagement for users [1-8].

In the future, the development of 3D content is anticipated to prioritize the enhancement of realism to achieve higher levels of immersion. A notable example of this trend is the incorporation of technologies such as haptic feedback, which allows users to physically interact with content. Additionally, advancements in web technologies are expected to improve accessibility to 3D content via the internet, facilitating seamless 3D experiences across multiple devices and platforms. The proliferation of 3D content creation tools is enabling both professionals and amateurs to produce 3D content more easily. This technological progress not only enhances user experiences but also aligns with industry demands and market trends, thereby broadening the application of 3D content across various fields. Looking ahead, a significant trend is likely to be the development of more intuitive and lifelike content.

Furthermore, there is a burgeoning interest in glasses-free 3D display technology among the various display devices designed for visualizing 3D content. These displays utilize a range of techniques, including parallax barriers, lenticular lenses, and light field displays [9-12]. Such technological advancements facilitate highly immersive entertainment experiences in 3D films and video games, while also serving as effective educational tools through the use of 3D models in medical and engineering training.

As 3D display technology continues to evolve and the applications for 3D content expand, it is essential to maintain ongoing improvements in content quality, technical reliability, and user engagement to ensure successful market penetration. In particular, with respect to user interaction, it is crucial to provide features that allow multiple creators and users to engage seamlessly without the need for specialized software installation.

The advantages of using a web-based service environment that enables user interaction with Multi-Device Integration in 3D media authoring tools, without the need to install specific programs, are as follows:

- Improved Accessibility: Users should be able to create and experience 3D content using only a web browser, making it easier for more users to access content through portable Multi-Device Integration (Smartphones, Leap Motion).
- Cost Reduction: By utilizing web-based tools without requiring additional software installation, and by using devices (smartphones) that users already own, production costs can be reduced.
- Ease of Collaboration: Multiple users can work simultaneously within a web service environment, facilitating collaboration.
- Platform Independence: Content should be compatible across various operating systems and devices.

In this paper, we design and implement an Interactive 3D Media Production (Interactive3D) system that allows for the creation of various interactive 3D media using complex devices in a web service environment. Interactive 3D consists of a scenario editor that provides scenario editing functions for creators, a complex device integration feature, and an interaction API for editing and playing back interactions. Each of these components will be described in detail in Chapter 2.

2. Interactive 3D Media Production Based on Multi-Device Integration

The Interactive 3D system developed in this research provides a diverse array of content services designed to enhance user engagement and optimize both educational outcomes and tourism experiences. This system is not merely a conduit for information dissemination; it also aims to enrich the immersive quality of learning and experiences by facilitating direct user interaction with the content. Such an approach promotes active participation in educational and tourism-related material, thereby contributing to improved learning results and a heightened quality of tourism experiences. Figure 1 illustrates examples of interactive educational and tourism content generated through the Interactive 3D system. The integration of multiple devices, specifically a portable smartphone in conjunction with Leap Motion technology, allows for convenient user interaction, ensuring both accessibility and a fluid interaction experience. In Figure 1(a), the content is centered on fire prevention education. Users engage interactively by responding to an alarm triggered during a simulated fire scenario. This method contrasts with traditional fire prevention videos, as it fosters active learning through hands-on experiences in fire response. Figure 1(b) depicts a scenario in which the user, while viewing a video related to a specific festival, receives real-time location information via GPS interaction, indicating the whereabouts of the ongoing festival.

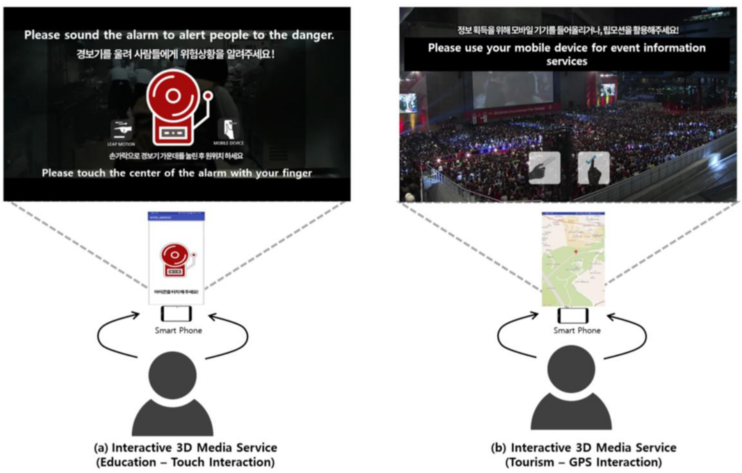

Figure 1. Examples of Educational and Tourism Content Services Created with Interactive 3D Using a Multi-Device Integration

By utilizing user interaction based on Multi-Device Integration, it is possible to create and provide content and services that not only engage users' interest but also encourage active participation, potentially leading to real-world educational and tourism experiences. As shown in Figure 2, this type of Interactive 3D is delivered as a web service environment via the internet.

To create interactive 3D media, authoring tools and a player for viewing interactive 3D media are included. The 3D media uses stereoscopic video that provides depth information through binocular disparity. Content creators can use Interactive 3D to produce content by selecting devices, defining interaction types, and setting interaction timings. Users can access the Interactive 3D content via a web browser and experience it according to the creator's scenario, using devices like smartphones or Leap Motion to interact with the 3D media.

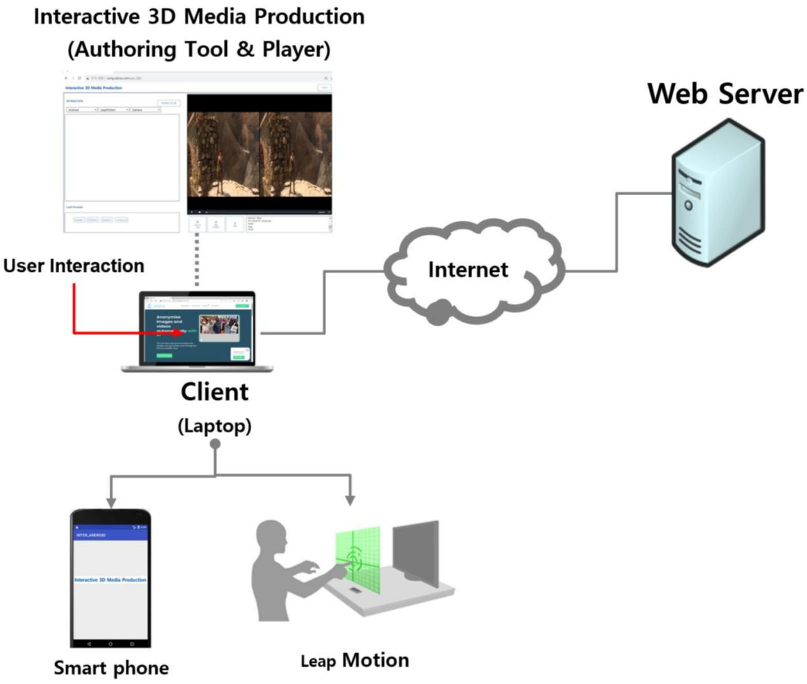

Figure 2. Interactive 3D Operation Diagram

Interactive 3D technology facilitates the creation and engagement with three dimensional media that incorporates user interaction. This technology comprises several components, including a scenario editor, multi-device integration, and an interaction API.

The scenario editor allows content creators to organize multiple 3D video clips into nodes that correspond with the narrative structure. The multi-device integration encompasses a smartphone, which offers portability for users, as well as Leap Motion, an affordable device that enables hand gesture recognition for interactive purposes.

Additionally, the interaction API provides editing functionalities for more than ten distinct types of interactions utilizing these devices, and it includes the Interactive 3D Media Player (I3D Player).

2.1 Scenario Editor

In this paper, as illustrated in Figure 3, the creator uses a scenario editor to structure scenes node by node, and integrates this with interactive media authoring tools to create interactive media on a node-by-node basis. When the interactive media authoring tool is executed, it utilizes the project ID and node ID information transmitted from the scenario editor to display the scenario information on the interactive media authoring tool's interface.

The scenario information provided is intended for the creator to edit interactions. It includes the overall structure of the scenario as well as the current scene details. Users can create interactive 3D media by utilizing the interaction editing and multi-device integration features provided by the interaction API to fit the story. The created interaction information is stored in the form of interaction metadata and can interact with the I3D Player.

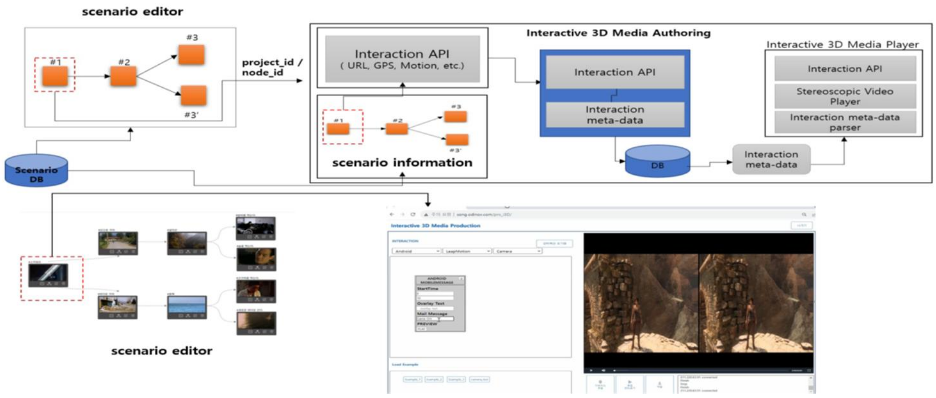

Figure 3. Interactive 3D Media Player using user's smart phone

The scenario editor sends data using the POST method, transmitting the scenario information message as shown in Figure 4. This information is used to display scenario details in the interaction editor. Using the provided scenario information in the interaction editor, the creator can review video story information, node thumbnail details, and the current interaction editing node information.


```
{
 "res_code" : 1,
 "res_msg" : "success"
 "images" : ["thumbnail_1.jpg", "thumbnail_2.jpg", "thumbnail_3.jpg"],
 "video_url" : "http://192.168.187.39/dScene/C[illegible].mp4",
 "video_title" : "City",
 "video_sec" : "00:03:12",
 "video_type" : "mp4"
 "video_resolution" : "1280 x 720"
}
```


Figure 4. Scenario information transfer successful result message

The "res_code" and "res_msg" fields confirm whether the scenario information transfer was successful, while the remaining fields provide the essential data required for rendering and interaction. Once the response is received, the interaction editor uses the returned information to visualize and manage the active scenario. Specifically, it loads:

- Video story metadata such as title, duration, type, and resolution
- Node-level thumbnails from the images array to support scene preview and navigation
- Current interaction node context, which is synchronized using the scenario identifier contained in the POST body.

By utilizing the returned JSON payload, the creator can review the video structure, inspect the relevant thumbnails, and continue editing the corresponding interaction node within the interaction editor. This client-server communication ensures that scenario authoring, previewing, and iterative modification are carried out in real time with consistent data across devices.

2.2 Multi-Device Integration Functions

In Interactive 3D, the functionality provided by composite devices, such as smartphones and Leap Motion, varies depending on the devices configured in the scenario editor. Smartphones utilize their built-in features to offer interactions such as Push, Pop Messages, GPS, mobile web services, sound, and phone functionalities.

In contrast, Leap Motion, on the other hand, provides Hand Interaction by tracking and recognizing hand and finger movements in 3D space. The process of integrating composite devices is illustrated in Figure 5. The flowchart in Figure 5 shows that after reading the interaction metadata, the system identifies the device information. It then determines whether to use an Android or Leap Motion device. For smartphones developed within the Android OS environment, they are referred to them as "Android" devices. When a smartphone is detected, the "Android controller" operates and connects via WebSocket. For Leap Motion devices, the "Leap Motion controller" operates. Each controller checks the interaction mode, recognizes user actions, and ultimately sends a completion message.

In the case of smartphones, I3D Player establishes a WebSocket connection with the smartphone's interaction app. Upon successful WebSocket connection, the interaction mode is verified, and the corresponding activity is executed. During activity execution, I3D Player pauses. If the user interaction in the activity is successful, a "Finish" message is sent to the WebSocket server. Once user interaction is confirmed to be functioning properly, I3D Player resumes and plays the next video.

For Leap Motion, no WebSocket connection is needed; the interaction recognition module operates directly within the web browser. When an interaction occurs, I3D Player pauses, and if the hand gesture interaction is successfully recognized, a "Finish" message is sent to the web server. After confirming that the user interaction is functioning correctly, I3D Player resumes and plays the next video.

In this paper, user interactions using the devices are differentiated based on the device characteristics. Smartphones have a dedicated app developed for interaction recognition, which works with I3D Player via WebSocket. Leap Motion, however, operates directly within the web browser, leading to a structural difference in how user interactions are managed. The following describes the interaction operations for each device and I3D Player.

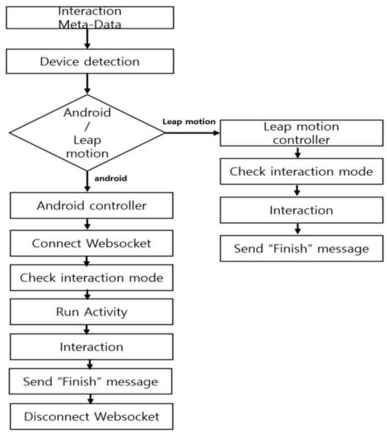

Figure 5. I3D Player control flow chart based on Multi-device Integration

The procedure for integrating I3D Player with a smartphone, as previously outlined, is depicted in the subsequent process. Figure 6 demonstrates the practical execution of a URL interaction on a smartphone.

1. Create the I3D Player.
2. Load the interaction metadata for playback into I3D Player.
3. When an interaction occurs during playback, pause the I3D Player.
   • Establish a WebSocket connection with the smartphone.
4. Send the URL interaction information.
5. The smartphone executes the interaction activity (URL Activity).
   • The user views the information on the automatically connected website.
6. After the user reviews the URL information and selects the exit button, a "Finish" message is sent to I3D Player.
7. The paused I3D Player resumes and plays the next video.

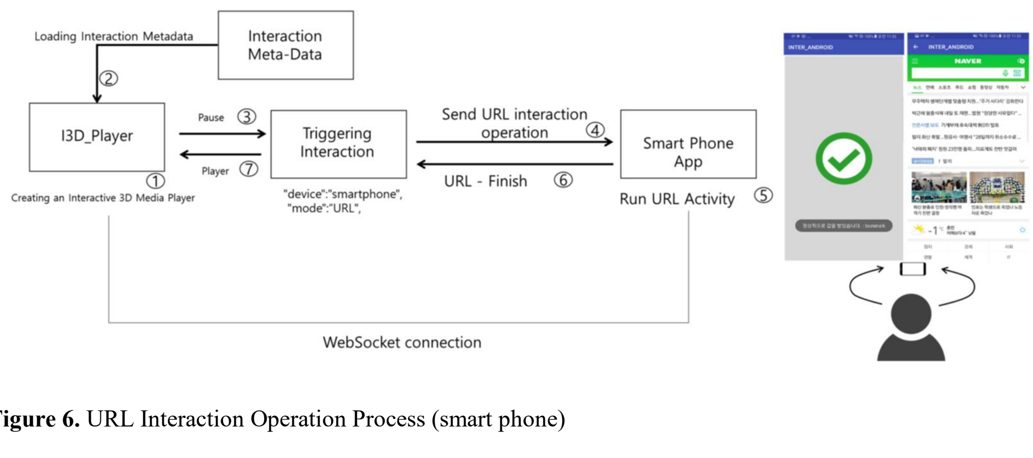

Figure 6. URL Interaction Operation Process (smart phone)

The procedure for integrating I3D Player with a Leap Motion, user interactions provide the functionalities of PUSH, TOUCH, GRAB, and PUNCH, as developed in previous research [13]. Unlike smartphones, Leap Motion does not have a separate app but instead features the recognition algorithms embedded in a web page. For example, Figure 7 shows the process of loading metadata in I3D Player and recognizing a GRAB motion using Leap Motion equipment.

1. Create the I3D Player.
2. Load the interaction metadata for playback into I3D Player.
3. When an interaction occurs during playback, pause the I3D Player.
   • Perform Leap Motion connection and verification.
4. Display the type of interaction on the screen.
5. The user performs the GRAB interaction.
6. If the GRAB interaction is recognized successfully, send the recognition results.
7. The paused I3D Player resumes and plays the next video.

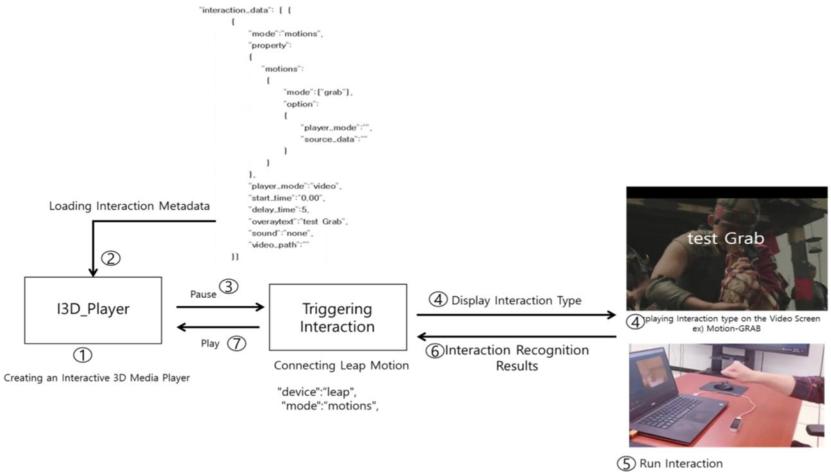

Figure 7. GRAB Interaction Operation Process (leap motion)

2.3 Interaction API (Application Programming Interface)

This paper provides information on the user interaction editing module, interactive 3D media player, device control and integration functions, and other features necessary for authoring interactive 3D media based on the multi-device integration, as illustrated in Figure 8. To support these diverse functionalities, the system was designed and developed in the form of an API (Application Programming Interface). The developed interaction API allows the technology to be utilized across various platforms for creating interactive 3D media content.

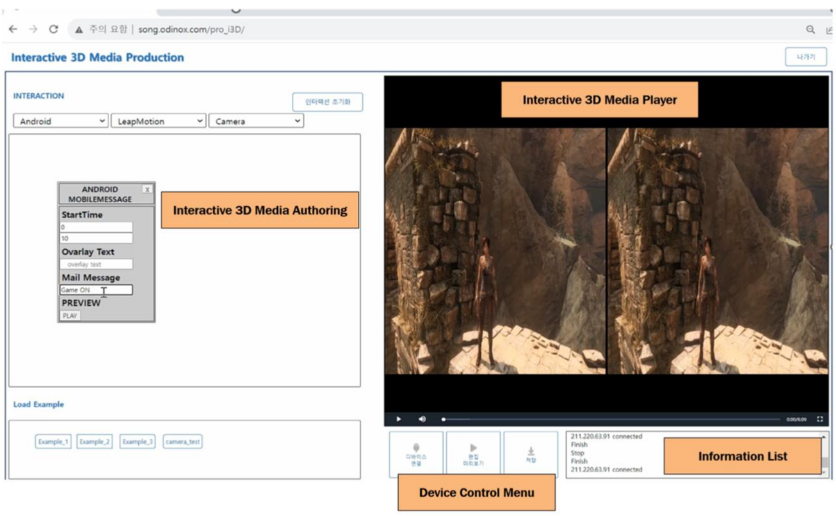

Figure 8. Interactive 3D Media Production GUI

This interaction API provides a GUI for editing, playback, and various functions to trigger and recognize interactions at specific times, depending on the device type. It also allows for the storage of user interaction metadata and enables I3D Player to load the same metadata, offering interaction features based on the Meta-Data information.

The main JavaScript files that operate within the interaction API are as follows:

- I3d.js: Handles key functions such as interaction creation, storage, and playback.
- I3d include.js: Defines global variables and classes for each connected element.
- Etri i3d plugin.js: Manages DIV layout and GUI creation during interaction editing.
- I3d canvas.js: Responsible for the I3D Player GUI.
- androidControl.js: Controls WebSocket connections for smartphone integration, manages communication messages, and links with I3D Player.
- leapcontrol.js: Controls Leap Motion connection, hand movement recognition functions, and links with I3D Player.

The main functions that operate within the i3D.js file include creating the player, setting interaction information, and loading the configured interaction metadata, as shown in Table 1. By utilizing the interaction API implemented in this paper, other projects can also load and create Interactive 3D Media.

Table 1. Usage Examples of Interaction API

Function	Description	Parameters and Examples
init: function(video name)	Initializes the I3D Player	video name: Specifies the ID name of the div where the I3D Player will be inserted. Example: I3D Player.init('TestPlayer');
createPlayer(option)	Creates the I3D Player with specified options	option: An object that includes settings for the player such as width, height, fit, interactive elements, resources, autoplay, and other settings. Example: I3D_Player.createPlayer({ width: 800, height: 450, fit: false, interactive: scene, resource: resources, autoplay: true });
playPlayerScene(scene)	Plays a specific scene in the player	scene: A JSON file containing the scene and interaction settings. Example: I3D_Player.importJsonFilePath(path); I3D_Player.playPlayerScene(scene);

i3d Interaction(options)	Configures the player with specified interaction settings	option: A JSON list containing interaction settings.
		Example:
		var i3d_Interaction = i3d.createInteraction();
		i3d_Interaction.device = interactive_data.device;
		i3d_Interaction.mode = interactive_data.mode;
		i3d_Interaction.property = interactive_data.property;
		i3d_Interaction.start_time = interactive_data.start_time;
		i3d_Interaction.delay_time =
		interactive_data.delay_time;

As shown in Table 2, androidControl.js provides functions for managing WebSocket connections and disconnections, as well as linking web user IDs with smartphone IDs. Additionally, it includes functions for sending messages via WebSocket and processing smartphone interaction information.

Table 2. Main functions in androidControl.js

Function Name	Description
socket event	Socket open and web user ID to smartphone ID linking function.
send socket msg	Sends messages via WebSocket.
connect android	Connects WebSocket.
disconnect android	Disconnects WebSocket connection.
use android motion	Sets smartphone transmission messages according to interaction information.

As shown in Table 3, leapcontrol.js provides functions for connecting with Leap Motion, recognizing interactions, and performing actions based on various gestures (e.g., PUSH, TOUCH, PUNCH, GRAB). It also includes functions for drawing the hand or selecting specific actions during interactions.

Table 3. Main functions in leapcontrol.js

Function Name	Description
connect leapmotion	Connects to Leap Motion device.
disconnect leapmotion	Disconnects and removes Leap Motion device connection.
use leap motion	Recognizes actions based on interaction information.
draw leap Hand	Calls functions that draw the hand during interactions.
Start_Push	PUSH interaction.
Start_Punch	PUNCH interaction.
Start_Touch	TOUCH interaction.
Start_Grab	GRAB interaction.

3. Results

To ensure proper functionality of videos produced using the Interactive 3D Media Production system across multiple devices, the setup is configured as illustrated in Figure 9. The testing environment consists of a web server hosting the Interactive 3D service, a laptop accessed by the user via a web browser, and multiple devices including a smartphone and a Leap Motion controller. An internet network is established to enable communication between the web browser and the smartphone, supporting seamless operation of the web-based service.

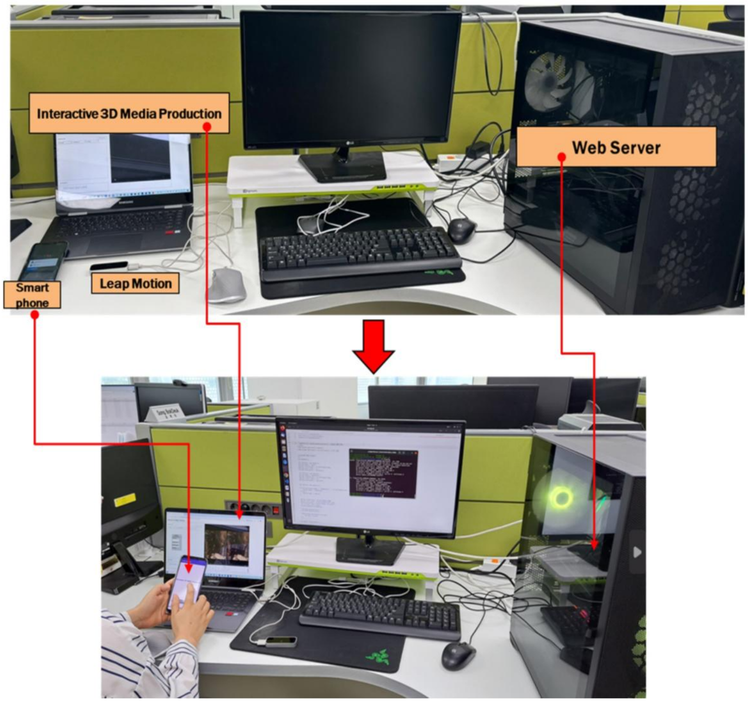

Figure 9. System Configuration Diagram for Interactive 3D Testing

The testing process is organized into interactions that utilize a smartphone and Leap Motion, as detailed in the Table 4. The smartphone interactions mainly focus on text messaging, accessing URLs, and GPS features. In the text messaging segment, users send and receive designated messages on their smartphones while the edited video plays. For URL access, a specific URL is sent to the user, enabling them to visit the related website. The GPS functionality is assessed by allowing users to see map information based on the GPS coordinates they input. The Leap Motion interactions are evaluated by checking the effectiveness of four gestures: TOUCH, PUSH, PUNCH, and GRAB.

Table 4. User Interaction Testing Procedure Using Smartphone and Leap Motion

Step	Smart Phone	Leap Motion
(1)	Launch the web browser (Chrome) installed on the laptop.	
(2)	Access the target 'Interactive 3D Media Production'. - Access URL (Local): http://localhost/pro i3D/	
(3)	Select 'Android Menu/User Interaction Type'. - User Interaction Types (3 types): URL, GPS, MobileMessage	Select 'Leap Motion Menu/User Interaction Type'. - User Interaction Types (4 types): TOUCH, PUSH, PUNCH, GRAB
(4)	Set the interaction trigger time and select the interaction preview function. - Interaction Trigger Time: 10 seconds	
(5)	Click the video playback button. - Video Info: LeftRight3D.mp4 (Side-by-side 3D video)	
(6)	Use the user's smartphone to check if the interactions (URL, GPS, MobileMessage) are recognized.	Use the user's Leap Motion device to check if the interactions (TOUCH, PUSH, PUNCH, GRAB) are recognized.
(7)	Repeat the above procedure 3 times for each interaction.	

The recognition of each interaction was tested by performing the process three times for each interaction type, as described above. A third-party examiner then reviewed and evaluated the recognition results from these three trials. Figure 12 shows the result screen displayed on the user's smartphone during the actual operation of the GPS interaction. When a GPS interaction occurs while watching 3D content, the user can check the interaction notification on their smartphone. By reviewing the provided GPS information, users can verify the GPS data intended to be served within the 3D content. This allows them to check both the video and the real-world location information depicted in the video, thereby enhancing the immersive experience of the 3D content.

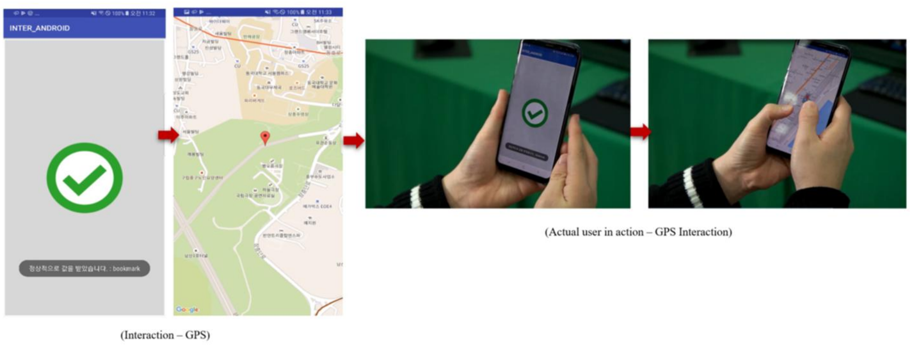

Figure 10. Actual Operation Screen - URL Interaction (Smart Phone)

Additionally, the Leap Motion was also tested according to the above procedure, with the TOUCH, PUSH, PUNCH, and GRAB interactions each being performed three times to confirm proper operation.

- TOUCH: Motion as if pressing a button with the index finger.
- PUSH: Motion of pushing with an open palm.
- PUNCH: Motion of pushing with a closed fist, similar to PUSH.
- GRAB: Motion of grabbing an object, then releasing the fist.

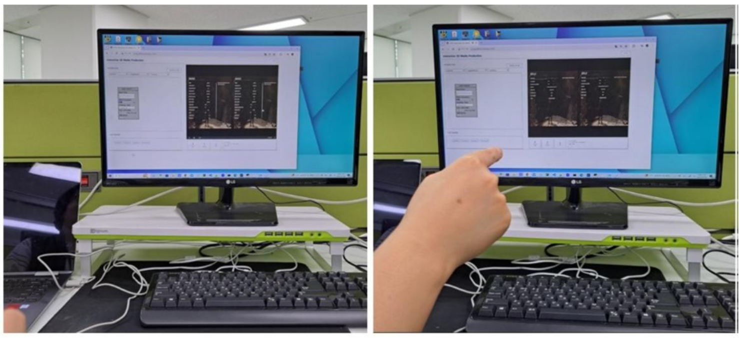

Figure 11. Actual Operation Screen - TOUCH Interaction (Leap Motion)

Figure 12 shows a screen where user interaction using a smartphone is functioning within an Interactive 3D environment. By configuring the message interaction to trigger 10 seconds after the start of the video according to the scenario, you can observe that the message interaction on the smartphone activates precisely 10 seconds after the video begins, as shown in the figure.

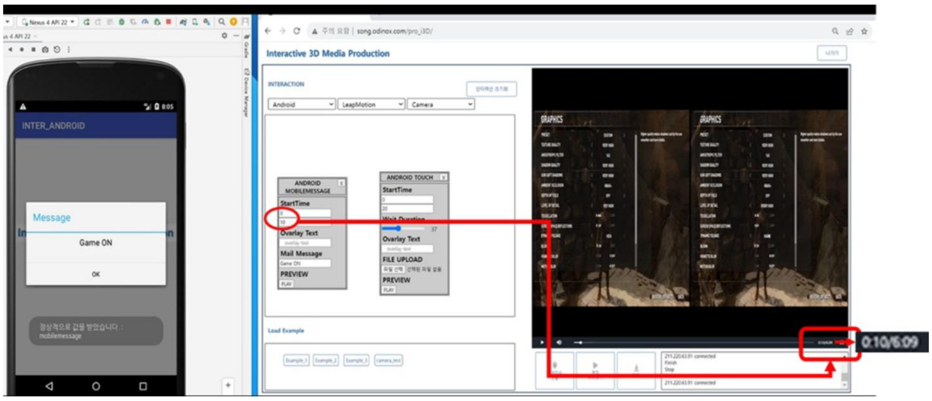

Figure 12. Interaction Trigger Time Verification (Smartphone, Message Interaction)

The experimental results presented in this study are derived from certified test reports verified by the Telecommunications Technology Association (TTA). Tables 5 and 6 summarize the validation outcomes, including the test results obtained using smartphones and the Leap Motion device. Each interaction behavior was evaluated a minimum of three times to ensure proper functionality and confirm stable performance.

User interaction testing was conducted using both smartphones and a Leap Motion device. For smartphones, three interaction types (URL, GPS, and Mobile Message) were tested, and for the Leap Motion device, four interaction types (touch, push, punch, and grab) were evaluated. Each interaction was repeated three times, and all trials were successfully recognized, demonstrating stable and reliable system performance across all interaction modes.

Table 5. Results of User Interaction Tests Using Smartphone

Test Items	Objective	Interaction Type	Times	Recognition Status (O, X)	Result
User Interaction: Smartphone	Three types of user interactions are provided	URL	Trial 1	O	The system provides three forms of user interaction (URL, GPS, MobileMessage)
			Trial 2	O	
			Trial 3	O	
		GPS	Trial 1	O	
			Trial 2	O	
			Trial 3	O	
		MobileMessage	Trial 1	O	
			Trial 2	O	
			Trial 3	O	

Table 6. Results of User Interaction Tests Using Leap Motion Device

Test Items	Objective	Interaction Type	Times	Recognition Status (O, X)	Result
User Interaction: Leap Motion Device	Three types of user interactions are provided	TOUCH	Trial 1	O	The system provides four forms of user interaction (TOUCH, PUSH, PUNCH, GRAB)
			Trial 2	O	
			Trial 3	O	
		PUSH	Trial 1	O	
			Trial 2	O	
			Trial 3	O	
		PUNCH	Trial 1	O	
			Trial 2	O	
			Trial 3	O	
		GRAB	Trial 1	O	
			Trial 2	O	
			Trial 3	O	

Additionally, to validate user interaction within the proposed multi-device integrated 3D Media Production and playback environment in a laboratory setting, we employed the Post-Study System Usability Questionnaire (PSSUQ) [14] to assess users' subjective experience. Four participants used the interactive 3D media authoring tool and player, and their feedback focused specifically on the accuracy of interaction recognition across devices. The study was conducted once and limited to individuals who had direct experience with the proposed system. The PSSUQ consists of 19 post-test survey items that generate three key metrics—System Quality, Information Quality, and Interface Quality—to evaluate the usefulness of the product. All 19 items were included in the survey, and the four participants responded based on their use of the interactive 3D media production system. Table 7 presents the reliability analysis of the PSSUQ, and the overall evaluation results are summarized in Table 8.

The average PSSUQ score for users' experience with the composite motion authoring tools and interaction functions was 5.85 on a 7-point Likert scale, demonstrating generally positive user satisfaction.

Table 6. The 19 items in PSSUQ

No.	Post-Study System Usability Questionnaire Items
1	Overall, I am satisfied with how easy it is to use this system
2	It was simple to use this system
3	I could effectively complete the tasks and scenarios using this system
4	I was able to complete the tasks and scenarios quickly using this system
5	I was able to efficiently complete the tasks and scenarios using this system
6	I felt comfortable using this system
7	It was easy to learn to use this system
8	I believe I could become productive quickly using this system
9	The system gave error messages that clearly told me how to fix problems
10	Whenever I made a mistake using the system, I could recover easily and quickly
11	The information (such as on-line help, on-screen messages, and other documentation) provided with this system was clear
12	It was easy to find the information I needed
13	The information provided for the system was easy to understand
14	The information was effective in helping me complete the tasks and scenarios
15	The organization of information on the system screens was clear
16	The interface of this system was pleasant
17	I liked using the interface of this system
18	This system has all the functions and capabilities I expect it to have
19	Overall, I am satisfied with this system

Table 7. The reliability analysis of PSSUQ

PSSUQ Classification	Number of Questionnaire
System Quailtiy	1-8
Information Quality	9-15
Interface Quality	16-18
Total	1-19

Table 8. Result of the user test based on the PSSUQ scale

User	Experience User
User_01	6.3
User_02	5.7
User_03	5.8
User_04	5.6
Average	5.85

4. Discussion

Recent advancements in interactive 3D media production tools have shifted the focus from device-dependent authoring environments to web-based, multi-device platforms that support greater accessibility and immersion. Unlike earlier studies that required specialized hardware or dedicated VR equipment, current systems allow users to interact with 3D content through web browsers, PCs, smartphones, and motion-based controllers, significantly lowering the barrier to entry. Real-time interaction within OTT platforms further enhances user engagement by enabling direct interaction with objects in video scenes to retrieve additional information, reinforcing findings that interactive content improves attention and learning effectiveness.

Contemporary authoring platforms, such as Unity MARS, Adobe Aero, STYLY, and WebXR-based tools, also provide cloud synchronization, spatial scenario design, and cross-device deployment. These are supported by multimodal input methods including hand tracking, gaze control, and wearable-based motion sensing. In parallel, AI-assisted authoring is emerging as a core trend, enabling automated scene generation, semantic tagging, gesture mapping, and natural language–based scenario branching. The proposed system—an interactive 3D media production framework based on multi-device integration—extends beyond conventional click- or touch-based workflows by supporting two-hand composite gestures and device-aware interaction editing. Its modular architecture allows each function to operate as a plugin, making it scalable and adaptable for diverse use cases such as education, advertising, virtual production, and XR storytelling. By integrating scenario editing, media uploading, and multi-platform synchronization, the tool simplifies the creation of real-time interactive content and promotes wider adoption of 3D media across industries. In the future, this research can be expanded to analyze user interaction behavior, apply AI for adaptive personalization, and connect seamlessly with AR/VR devices to deliver fully immersive 3D media experiences. Such advancements are expected to further enhance usability, engagement, and content production efficiency in educational, commercial, and entertainment domains.

5. Conclusions

This research facilitates user engagement with a variety of interactive 3D media through standard web platforms, personal computers, and smartphones, all at an accessible cost. It encompasses user scenarios alongside a range of interactive 3D media that align with these scenarios. The primary objective of this study is to foster the development and appreciation of immersive interactive 3D media, which is anticipated to enhance the efficient production of engaging and informative educational and advertising materials. By integrating video element control technologies for user interaction and improving the interactive 3D media player, the creation process of interactive 3D media is expected to become more efficient. The interactive 3D media authoring tools developed in this research are specifically designed for Multi-Device Integration. When utilized within Over-The-Top (OTT) platforms, these tools enable users to interact with 3D content in real-time during streaming, thereby enriching the viewing experience. For instance, users can select specific objects during video playback to access additional information, allowing OTT service providers to deliver unique content and enhance viewer engagement. The interactive 3D media authoring tools presented in this study feature a modular architecture that supports the integration of various interactions. Each function is compartmentalized and can be configured as a plugin for alternative authoring tools, thus facilitating streamlined Multi-Device Integration.

Acknowledgments: This work was supported by Electronics and Telecommunications Research Institute (ETRI) grant funded by the Korean government. [25ZC1100, The research of the basic media・contents technologies]

Conflicts of Interest: There is no conflict of interest among the authors of the manuscript.

References

[1] S. Y. Lee, D. H. Cho, Y. H. Won, and M. C. Kim, "Special issue on realistic and immersive media technologies," ETRI Journal, vol. 44, no. 1, pp. 7-9, 2022.

[2] G. W. Young, G. Dinan, and A. Smolic, Realtime-3D Interactive Content Creation for Multi-platform Distribution: A 3D Interactive Content Creation User Study, Virtual, Augmented and Mixed Reality(HCII 2023), 2023.

[3] B. Spittle, M. Frutos-Pascual, C. Creed, and I. Williams, "A review of interaction techniques for immersive environments," IEEE Transactions on Visualization and Computer Graphics, vol. 29, no. 9, pp. 3900-3921, 2023, doi: https://doi.org/10.1109/TVCG.2022.3174805.

[4] H. Kharouband, M. Lataifehand, and N. Ahmed, "3d user interface design and usability for immersive vr," Appl. Sci., vol. 9, no. 22, pp. 1-29, 2019, doi: https://doi.org/10.3390/app9224861.

[5] E. K. Johnson and J. Murray, XR Content Authoring Challenges: The Creator-Developer Divide, CRC Press, Boca Raton, 2021.

[6] C. H. Lin, J. Gao, L. Tang, T. Takikawa, X. Zeng, X. Huang, K. Kreis, S. Fidler, M. Y. Liu, and T. Y. Lin, "Magic3D: High-Resolution Text-to-3D Content Creation," IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2023.

[7] M. Potenziani, M. Callieri, and M. Dellepiane, "Publishing and Consuming 3D Content on the Web: A Survey," Foundations and Trends® in Computer Graphics and Vision, vol. 10, no. 4, pp. 244-333, 2018, doi: https://doi.org/10.1561/0600000083.

[8] R. C. Mota, R. A. Roberto, and V. Teichrieb, "Authoring Tools for Augmented Reality: An Analysis and Classification of Content Design Tools," IEEE International Symposium on Mixed and Augmented Reality, 2015, doi: https://doi.org/10.1109/ISMAR.2015.47.

[9] Y. Cho, M. Park, and J. Kim, "Xave: Cross-platform based asymmetric virtual environment for immersive content," IEEE Access, vol. 11, pp. 71890-7190420, 2023, doi: https://doi.org/10.1109/ACCESS.2023.3294390.

[10] lookingglass: Specializes in light field displays for 3D content without the need for glasses. [Online] Available: https://lookingglassfactory.com

[11] Dimenco: Offers lenticular lens-based 3D displays focused on immersive experiences. [Online] Available: https://www.leiainc.com/leiasr

[12] Asus: ProArt Studiobook 16 3D OLED. [Online] Available: https://www.asus.com/

[13] B. D. Song, H. K. Choi, and S. H. Kim, "Complex hand interaction authoring tool for user selective media," Electronics, vol. 11, no. 18, pp. 1-14, 2022, doi: https://doi.org/10.3390/electronics11182854.

[14] J. R. Lewis, "Psychometric Evaluation of the PSSUQ Using Data from Five Years of Usability Studies," International Journal of Human–Computer Interaction, vol.14, no. 3-4, pp. 463-488, 2002.