Augmented Reality Musical Service Part 1 for Non-face-to-face Watching by Multiple Audiences

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Abstract— We propose an augmented reality(AR) musical service in which virtual actors perform on the stage of the real world, even if actors and audiences do not meet. The AR musical service proposed in this paper applied augmented reality technology using an AR platform we are developing. Here, part 1 of the augmented reality musical service is defined as the main performance of the augmented reality based musicals. First, we generated a map of a real stage space in the real world that can provide non-face-to-face musicals using AR technology. In addition, we created an AR application that can show virtual actors, their performance, their songs, and virtual stage props and effects appearing in the proposed AR musical service. Finally, we used AR technology to allow multiple audiences to enjoy the proposed AR musical service together in the stage space of the real world. In this paper, it was possible to confirm whether multiple audiences could watch the proposed AR musical service together in which the virtual actors perform on a real stage as if it were real musicals.

*Keyword*s—**Augmented Reality(AR), Musicals, AR Musical Service, Multiple Audiences, Virtual Actor.**

I. INTRODUCTION

Recently, with the rapid spread of 5G and WiFi, the communication environment is improving so that many people can seamlessly send and receive large amounts of data on the Internet. The improvement of the communication environment has allowed service providers to have a wider range of choices for services that can be provided to their users. Therefore, the application service field is gradually expanding to contents and services related to 3D data as well as large-capacity high-definition video.

Augmented reality technology is being chosen by experts as one of the technologies that can drive future growth. Driven by this technological demand, many global IT companies have been developing platforms and development tools that can support augmented reality services and technologies. In addition, development of various equipment such as smart glasses for AR using a transparent display where users can enjoy augmented reality services, gloves and suites that can deliver tactile sensation is also in progress.

We are living in an era of New-Normal, where non-face-to-face has become a daily routine with the advent of CoVID-19. Such an environment of the times explosively increases the demand for augmented reality technology and accelerates the speed of development for related technologies. Augmented reality technology can provide users with an extended experience that can transcend temporal and spatial constraints by using virtual objects. In addition, non-face-to-face services that provide services without meeting people in person are spreading throughout society. Therefore, we decided to try creating an AR Musical service in the field of culture and arts that allows you to enjoy musical performances non-face-to-face with actors on the performance stage.

In the past, early studies related to performances or shows using augmented reality or virtual reality technology have been conducted. Correa et al. [1] proposed GenVirtual, an augmented reality musical game, to help patients with learning disabilities. By placing musical and visual elements, the therapist can create different treatment scenarios for each patient. Poupyrev et al. [2] proposed Augmented Groove capable of performing music using AR technology. Use a keyboard, dial, or simulated traditional music controller. Lee et al. [3] proposed a system to apply projection-based AR for real-time masking of dynamic objects in live performances such as plays, dances, and musicals.

In addition, Cavazza et al. [4] proposed the integration of a small-scale real-time immersive interactive storytelling system. They described the system's behavior for the implementation of excerpts from the classic 19th-century novel Madame Bovary, where the user took on the role of one of the characters and demonstrated the ability to influence the story's development with his actions. Brown et al. [5] proposed a multi-user virtual reality story experience including a set of guided camera techniques and a set of gaze-dispersion techniques to determine the best way to engage different users into the same story.

However, in previous studies, it was difficult to match the virtual objects and the real world naturally like the actual performances watched by the audience. In addition, it was difficult for multiple audiences to enjoy AR services at the same time. The contents of this paper we proposed are as follows. First, we briefly look at an AR technology used to create the proposed AR service in chapter 2. And we will explain the proposed AR Musical service where virtual actors perform on real stage. Then, we will look at the AR musical service that actually operates in

the experimental environment we presented, and check the experiment and test results. Finally, the conclusion and future work will be described.

II. BRIEF SUMMARY OF ONAR PLATFORM

We are developing an OnAR platform with a structure consisting of a server and clients by improving the initial model [6] of the platform for making AR services. In this chapter, we will take a very brief look at only the necessary parts of the OnAR platform to create the proposed AR Musical service.

A server-side consists of a Communication manager, an AR Room manager, a Map manager, an AR Application manager, and a Function Extension manager on the OnAR platform. In addition, a client-side consists of the Communication manager, the Map manager, and the AR Application manager when using the same world coordinate system as the server.

A. Communication manager

In order for users to use AR services provided by the OnAR platform, the server and clients must be connected to each other so that data can be exchanged through the communication manager. The server to which the user's clients are connected sends the list of AR Rooms created by the administrator to the clients. When the AR service starts after clients enters the desired AR Room, the server sends necessary data after checking all AR Application and Map information of the client. In addition, the server receives the information sent by each user's client and sends them so that the users can share the information of all users in the AR Room synchronized by a Synchronizer of the AR Room manager.

B. AR Room manager

When a user's client connects to the server of the OnAR platform, users are connected to the AR Room manager through the Communication manager. AR Room manager provides a waiting area for clients of multiple users to access and the AR Room creation/management/destruction functions where AR services can be enjoyed. In addition, the Synchronizer of the AR Room manager gives multiple users the feeling of experiencing the AR service together in the AR Room.

C. Map manager

AR services need to accurately recognize a real three-dimensional space in the real world so as to provide users with a sense of immersion. Devices commonly used by users often have only a monocular camera. However, it is very difficult for devices with a monocular camera to accurately recognize scale and distance information of real objects. Therefore, we process the map on the OnAR platform with an extended and modified algorithm[7] from ORB-SLAM[8] that recognizes three-dimensional spaces in the real world only with a monocular camera. Map manager creates, modifies, stores and reads maps in the real space of the real world of AR services to be provided to users, and manages them with DB.

D. AR Application manager

AR Application manager has AR applications corresponding to the map with 3D spatial information of the real world. The AR application manager can create and provide multiple AR applications corresponding to a map with spatial information of one real world. Therefore, the OnAR platform can provide various AR services by different AR applications depending on the purpose and target of the AR service, even if they have the same spatial information of the real world.

E. Function Extension manager

On the OnAR platform, the client-side can expand functions by using AR devices with various functions. On the other hand, the server-side uses the Function Extension manager to extend functions on the OnAR platform. Using this manager, the administrator of the platform can provide extended functions such as 3D mesh generation algorithms [7][9][10] and a marker recognition technique [11].

III. PROPOSED AR MUSICAL SERVICE

We proposed AR Musical service while imagining a musical performance where virtual objects and stage space of the real world naturally harmonize. Due to COVID-19, the current real world has become non-face-to-face daily life. In this period of time, the proposed AR Musical service can be a good example of non-face-to-face performance services.

Figure 1. Virtual modeling of a musical stage.

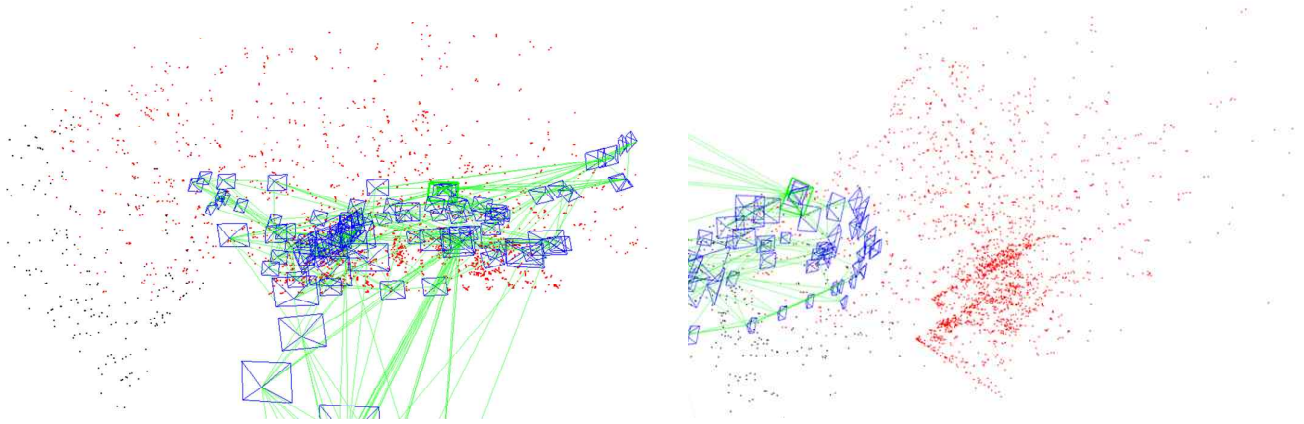Figure 2. Musical stage in the real world.

Figure 3. Map for AR Musical.

With proposed AR Musical service, audiences can enjoy musical performances even if they don't go directly to the musical venue, or even when actors and they do not meet. Figure **1** shows a virtually modeled 3D space before actual stage production to create the proposed AR Musical service. The left image of Figure **1** shows the front view of the AR Musical stage, and the right image shows its right side view.

A. Map

We were installed the musical stage of proposed AR Musical service virtually modeled in Figure 1 as it in the real world as shown in Figure 2. We made the AR Musical service to be able to replicate the musical stage like an AR WinterVillage[12] service. The walls and floors that are the background of the stage can be easily printed out by a printing service company. Also, stage props placed on the stage can be easily obtained on online markets. Therefore, the proposed AR Musical service is relatively easy to install and move on the stage so that many people can enjoy it in different places at the same time.

We created a map using the OnAR platform to provide AR Musical services on the musical stage created in Figure 2. In the actual stage space shown in Figure 2, the administrator of the OnAR platform created the map using the Map manager on the client. Figure 3 shows the front view and the right side view of the created map used in the AR Musical service, respectively.

In Figure 3, we can see the shapes of each prop as three-dimensional points for the props on the stage in particular. Accurate three-dimensional points recognized when creating the map help virtual actors and real props to perform natural musicals. Using the stage background and stage props shown in Figure **3**, virtual actors appearing in the proposed AR Musical service dance and perform.

B. AR Musical application

We chose virtual actors as cats among animals that are friendly to people and children love. Figure 4 shows five anthropomorphic cats appearing as virtual actors on the proposed AR Musical service. In order to enable these virtual cats to perform musical acting like real actors, Unity[13] program was used to perform various stage direction effects, creation of virtual actors, and animation rigging work.

Also, as shown on the right image of Figure 4, we can see a screenshot for the initial screen of the AR application to obtain the proposed AR Musical service. All virtual cat actors appear in the AR application. Since it is a musical performance, the

Figure 4. Initial screens.

story is mainly developed with virtual cats dancing and singing. The running time of our proposed AR Musical service is about 2 minutes.

Augmented reality is not real, but needs to be immersed in reality, so we tried to add elements such as real performances and movies to the proposed AR Musical service. First of all, we imagined a musical or theater performance. Audiences enjoy musical performances of acting, dancing and singing performed by actors on stage. After the performance is over, the audiences take pictures with the actors who have appeared, receive autographs, and even give flowers as a sign of appreciation for the good performance.

In this paper, we created the proposed AR Musical service produced using the AR technology to be as similar to actual musicals as possible. The proposed AR Musical service provides audiences with musicals performed by virtual actors on the actual stage. We defined this performance as part 1 of the proposed AR Musical service in this paper.

IV. EXPERIMETAL RESULTS

TABLE I. TEST ENVIRONMENT OF PROPOSED AR SERVICE

Side	Server	Client
Type	PC	Tablet PC
OS	Windows 10	Windows 10
CPU	Intel i7-8809G	Intel i7-8650U
RAM	16GB	16GB

In this chapter, let's look at the experimental environment built to provide AR Musical service in this paper. TABLE 1 shows the server and client environments used by OnAR platform for our proposed AR Musical service.

First, the server side is a PC type and wired to a wireless access point(AP). As can be seen from Table 1, the server specification uses a high-performance mobile 8th generation Intel CPU and 16G memory.

Next, users who are audiences can enjoy proposed AR Musical services while holding their devices on the client side. In addition, the real world visible to the user is minimized, and the screen of the client where the AR Musical service is visible through the rear camera is made larger. Therefore, we chose the client as a Tablet PC with a relatively large screen and an 8MP camera on the back. The specification of the client used the 8th generation Intel CPU for mobile and 16G memory. In the experiment of the proposed AR Musical service, the number of clients per AR Room was 2~8 units.

Also, since the client is a Tablet PC, a direct wired connection to the server was not possible. Therefore, the clients used in the proposed AR Musical service connected to the server via WiFi using a wireless AP.

We show various experimental results of the proposed AR Musical service using the OnAR platform by using the map of the actual stage space of the AR Musical service created in Section 3.A and the AR Application created in Section 3.B. We created an AR Room that each audience can access with the OnAR platform.

Figure 5 shows multiple audiences watching the proposed AR Musical service with their clients together. In addition, we created the environment of our AR Musical service so that audiences can sit and watch with chairs so that they can regard it as a real concert hall. As can be seen in Figure 5, audiences who watch together in AR Room can experience the proposed AR Musical service as if they were watching a performance in the same musical venue.

Of course, the proposed AR Musical service does not provide audiences with just sit-down view as shown in Figure 5. Figure 6 shows a scene where audiences watch the AR Musical

Figure 5. Multiple audiences.

Figure 6. Views from various locations.

services at various locations with clients. In order for audiences to watch AR Musical services while moving without sitting in a fixed seat, the location and posture of the audiences' clients must be estimated in real time and synchronized within the AR platform. Even if audiences enjoy our AR Musical service in various locations, the proposed AR Musical service provides them with an immersive feeling as if they enjoy a real musical performance in harmony with the stage and stage props.

Figure 7 shows the various stage effects that occur while audiences watch a musical performance. If it's a real musical performance, it's possible to set off firecrackers and blow pollen, but it's difficult to show the feelings of actors directly. As can be seen in Figure 7, the proposed AR Musical service provides a variety of stage effects in which virtual cat actors send virtual hearts to other actors, shoot firecrackers in the air, and blow pollen.

With the sudden appearance of COVID-19, many musicals, plays, and exhibitions have also been suspended. However, many audiences watched, experienced, and enjoyed the proposed AR Musical services. Part 1 of the AR Musical service was interesting and fun for everyone, regardless of age or sex. In particular, the children were very amazed as they watched the screens of their clients where virtual cat actors were singing, dancing, and acting even though there were no actors on the real musical stage.

We were able to confirm the possibility of AR technology that can transcend temporal and spatial constraints and provide extended experiences to audiences using virtual objects through the AR Dinosaur[14] service, the AR WinterVillage[12] service, and the proposed AR Musical service.

V. CONCLUSION AND FUTURE WORKS

We hope the proposed AR Musical service will be a relationship that develops together without overlapping or conflicting with performances where real people appear as actors.

In this paper, we proposed augmented reality Musical service in which virtual actors sing and act on a stage in the real world. The proposed AR Musical service used the OnAR platform in order to apply AR technology. First, we created a map of musical stage space in the real world using the AR technology to show the AR Musical service to the audiences. And, we created an AR application that can show virtual objects –various actors, performances, props, stage effects, and so on– appearing in the proposed AR Musical service. Moreover, we applied the AR technology to allow multiple audiences to experience the proposed AR Musical service in the real world with the musical stage. In this paper, we confirmed the proposed AR Musical service that allows multiple audiences to experience the AR service together in various experimental environments.
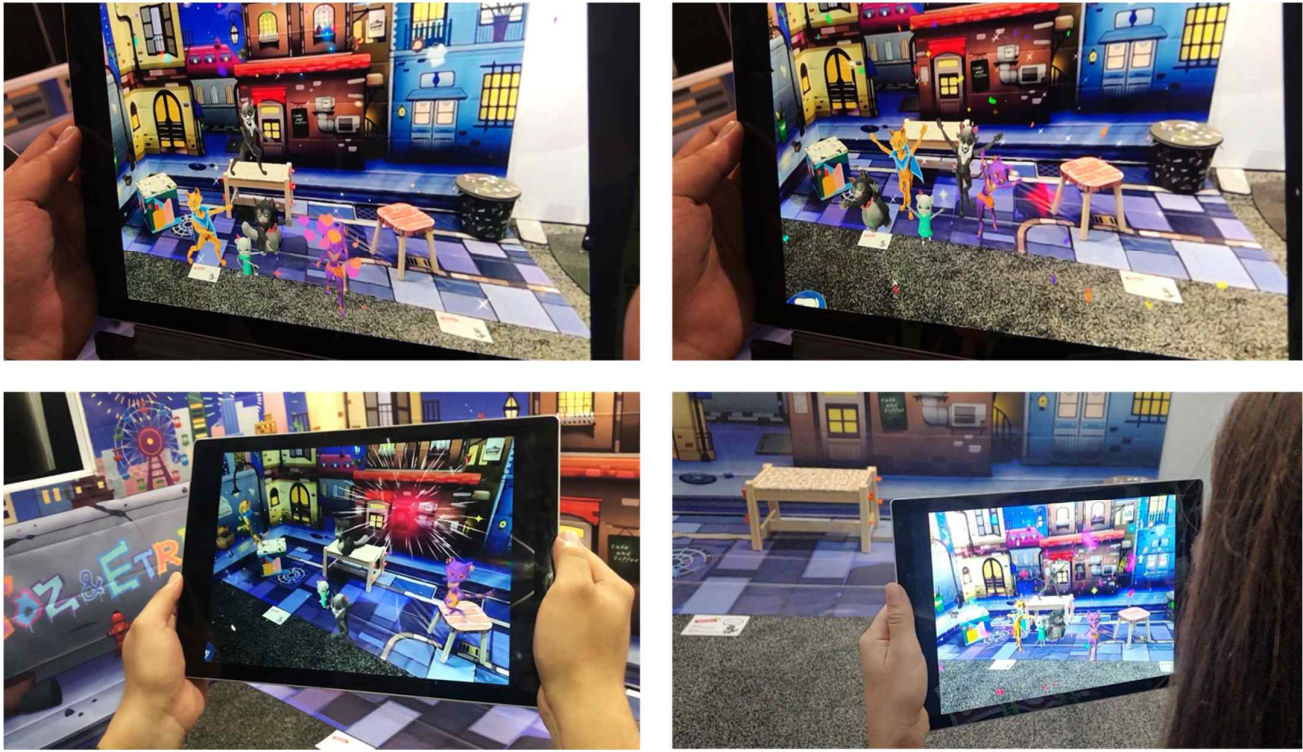
Figure 7. Augmented stage effects.

Earlier, we defined the main performance of a musical performance as part 1. In this paper, we focused only on part 1, which is the main performance of the musicals. We plan to do additional research on Part 2, an after-party event for the audience and virtual actors after the musical performance is over. In addition, we hope to develop improved AR platform technology and pioneer business areas by utilizing AR devices made by various companies.

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