Mixed Reality Pre-visualization for Filmmaking: On-set Camera-work Authoring and Action Rehearsal

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Abstract—**In the pre-production stage of today's filmmaking, PreViz, pre-visualizing a desired movie scene with CGI, is used for sharing final images of movies. In this paper, we propose MR-PreViz as an advanced approach that utilizes MR technology in PreViz. MR-PreViz makes it possible to merge real backgrounds and the computer-generated humans and creatures in an open set at an outdoor location. At the demonstration at ISMAR2007, we demonstrated two subsystems used at the shooting site for verification of the systems. The first one is a MR image capturing and compositing system, which is the core hardware of the MR-PreViz system. The second one is the MR action rehearsal system which enables users to practice sword fighting actions while confirming enemies' actions through a head mounted display in front of them. These systems with the physical set successfully attracted users to our technology while feeling immersed in a movie.**

***Index Terms*—Mixed Reality, Filmmaking, Pre-Visualization, Action Rehearsal, Camera-Work Authoring.**

I. INTRODUCTION

According to developing mixed reality (MR) technologies, many entertainment applications of MR technology are proposed [1, 2]. This indicates that MR technology has an ability to become a widely used method for creators of art and entertainment. As is well known, movies are the highest peak of entertainment. Therefore, the film industry has a huge market and potential. Technologies that increase efficiency in filmmaking are required.

In the preproduction stage, storyboards have been traditionally used to illustrate the director's intention. However, it is not difficult to imagine the limitation of storyboards for smooth image interpretation. Recently, pre-visualization (PreViz) [3], which is sometimes called animatics, has been used to further develop the storyboard. PreViz is a technique based on computer generated images for visualizing action scenes, camera angles, camera blockings, lighting conditions, and other situations and conditions before the actual shoot.

To these ends, we have already started the MR-PreViz project that aims to develop technologies assisting filmmaking by utilizing MR technology [4]. MR-PreViz makes it possible to merge real backgrounds and computer-generated humans and creatures in an open set at an outdoor location. In this paper, we introduce two prototype systems of the MR-PreViz system and reveal its potential. To this end, we go through an assumed scenario for actual use of the MR-PreViz by implementing and demonstrating its systems. An overview of the MR-PreViz project is introduced in section 2.

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II. MR-PREVIZ PROJECT

2.1 Basic concept of MR-PreViz

The typical filmmaking process has the following three stages:

- ***Preproduction stage:*** Planning, scripting, casting, location hunting, writing storyboards, and constructing props
- ***Production stage:*** Rehearsals, actual shooting, and special effects
- ***Postproduction stage:*** Film editing, sound mixing, and visual effects (VFX)

MR-PreViz consists of many subsystems to provide PreViz movies by superimposing pre-produced CGIs onto the actual shooting scene in the preproduction stage. MR-PreViz is mainly targeted to be used outdoor and not only in a motion picture studio. Thus, the MR-PreViz movies are made at the location site by trying various camera positions and angles and by changing footage and/or camera blocking. At the same time, the camera-works are marked up and stored as digital data to be used in the actual shooting.

2.2 General workflow

In filmmaking, the first step is to establish a plan and to make a plot based on that plan. A screenplay is written next where you can find actors, words and actions. Traditional storyboards and full CG PreViz are used at this stage to visualize ideas of an author or director. MR-PreViz is not a replacement for these traditional PreViz techniques but actually a powerful assistant to effectively visualize scenes that are not easily expressed.

The workflow of filmmaking using our subsystems is as follows (Fig. 1).

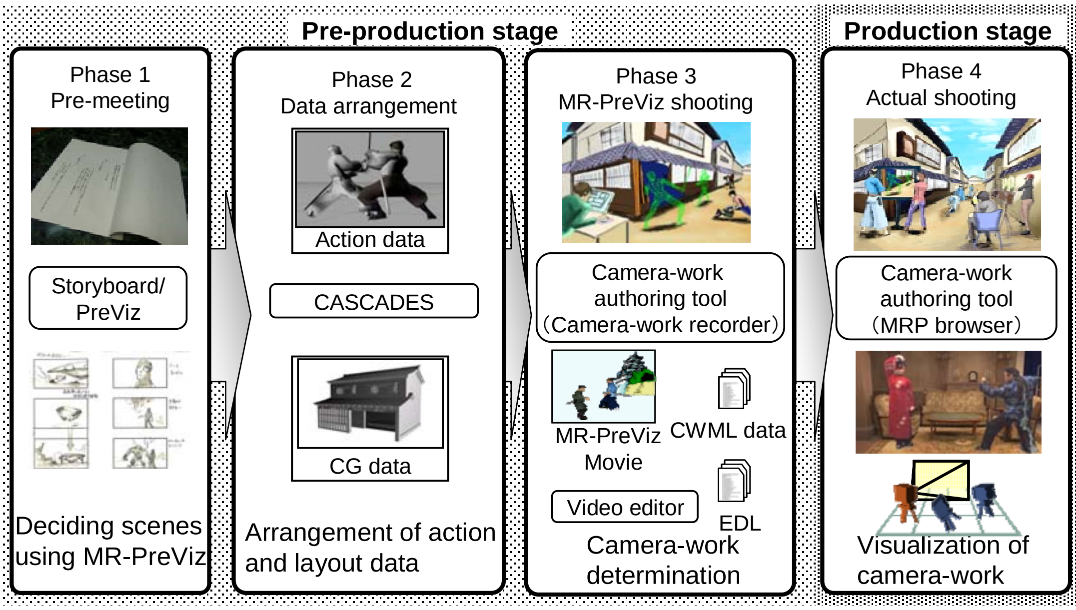

Fig. 1. Workflow of the MR-PreViz.

1) Selecting scenes suitable for MR-PreViz
   Selects scenes that should be checked using MR-PreViz, after making rough PreViz of full CG.
2) Preparing data materials required
   Collects CG character data, animation setting data, and action data before making MR-PreViz movies. Action data of different kinds have to be edited using CASCADES (Computer Aided SCene & Action DEsign System) at this stage. CASCEDES is a subsystem of MR-PreViz introduced in a latter chapter of this paper.
3) Placing CG objects
   Designs MR space by placing CG objects and action data collected and edited in step (2) above in the coordinates of the real world using CASCADES on a PC. This is a preparation before going to the shooting site.
4) Making MR-PreViz movies at the shooting site
   Contextualizes the layout made by CASCADES to the MR space at the actual shooting site and performs MR-PreViz using Camera-Work Authoring Tools. By repeated trial and error at this stage, you can significantly reduce the cost of actual film shooting.
5) Application to actual shooting
   Applies movies and data taken in the step (4) to the actual shooting. Actors and staffs can share ideas and images by seeing MR-PreViz movies shown on the MRP browser [4].

2.3 On-set MR-based systems in MR-PreViz

On-set visualizing subsystems are the core of the MR-PreViz project. Moreover, this is the most appropriate example to utilize the expressive power of MR technology in MR-PreViz. For on-set systems, we propose following the subsystems, detailed below, in MR-PreViz:

- **MR-PreViz image capturing and compositing system** renders MR-PreViz composite images for indoor and outdoor environments using a digital HD camera and rotary encoders. This is the core hardware system of the camera-work authoring tool. This system aims to support camera-work intuitively by using an actual shooting camera. This system is assumed to be used in phase 3 of the workflow mentioned in section 2.2.
- **MR action rehearsal system** visualizes MR composite images from the first-person perspective for action rehearsal. The users of the system practice action while confirming another person's action viewed in front of them through a head mounted display (HMD). This system is assumed to be used after phase 4 and before phase 5 of the workflow.

III. RELATED WORKS

A supporting system for filmmaking utilizing MR technologies was proposed in "2001: An MR-Space Odyssey" [5]. That system makes it possible to superimpose CGIs which are to be composed in the post-production stage onto real backgrounds. This system realized an on-set VFX system that enables the visualization of VFX in real-time from a first-person perspective and an objective view simultaneously.

This however is different from our system in the following ways.

- The goal of the MR-PreViz project is pre-visualizing final images of the movie at the pre-production stage in filmmaking
- Compared to the image quality of the MR composite image in that system[5], MR-PreViz enables it to be rendered in high definition (HD) MR composite images by using offline rendering
- The synthesized CG character's action scene is pre-recorded and designed using our design tool. 3D Videos [6] are newly adopted as action data for recording the appearance of action with any wardrobe.

One of the other approaches using mixed reality technology in filmmaking is to make an interactive storyboard at the preproduction stage [7]. This system relies on fiducial marker for registration. The other approach is MR-based authoring system for CG character animation [8]. This system proposes immersive content authoring which allows user to create their contents intuitively by exploiting the physical world as a user interface. However, these systems are unsuitable for determining camera-work and making PreViz movies.

In the remainder of this paper, we introduce the technical details of the implementations of these subsystems.

IV. MR-PREVIZ IMAGE CAPTURING AND COMPOSITING SYSTEM

4.1 Overview of the system

In the MR-PreViz system, pre-visualizations are generated for sharing images of the final movie and for considering camera-work and camera blocking. The targets of our MR-PreViz system are scenes where computer-generated creatures or vehicles play some role and also live action scenes where actors play their roles.

To composite real backgrounds and CGIs, the MR-PreViz image capturing and compositing system, which is a core hardware system in MR-PreViz shooting, is introduced in this demonstration. This system aims to be a supporting tool for determining camera-work, camera blocking, and framing while adhering fundamentally to the traditional style of filmmaking. Therefore, the dedicated equipment for filmmaking such as a digital HD camera (Sony HDW - F900R), a zoom lens (Canon HJ22ex7.6B IASE), a tripod, and a camera head are adopted for this system. Rotations of camera, panning and tilting angles, are detected by the rotary encoder built on the tripod for superimposing CGIs into camera images. Lens-related parameters such as zoom value and focal length are also detected by the lens encoder built in the zoom lens and are utilized for composition. By using this information, the MR-PreViz image capturing and compositing system renders and visualizes the MR-PreViz movie in real-time at the shooting site. Fig. 2 shows an aspect of the system on the set and composite image rendered by the system.

Fig. 2. Aspect of MR-PreViz image capturing and compositing system. (Left: Appearance, Right: Screenshot of composite images)

4.2 Camera-work authoring

In MR-PreViz, we define "camera-work authoring" as the collective term that indicates the process for determining framing, action scenes, position of the camera, camera angle, camera transition, and camera blocking by the director with collaboration from the cinematographer. To increase efficiency of these creative works, we are developing camera-work authoring tools [4].

With the increasing number of participators in today's epic movies, it is difficult for the director to communicate with his staff without them misunderstanding his ideas. In this research, we aim to propose supporting tools which enable a director to communicate with a staff by visualizing his/her ideas.

In particular, the following three functions are proposed for the authoring tools:

(a) Determining camera-work by visualizing composed images while manipulating a real camera

(b) Recording the result of the determining camera-work in CWML

(c) Visualizing and interpreting recorded data

The function of (a) and (c) are utilized in Phase3 and Phase4 of Fig. 1, respectively. The function of (b) is aimed to be an intermediate between them. MR-PreViz image capturing and compositing system are used for (a).

4.3 Features of the system

The features of the system are as follows.

Methods for composition of real backgrounds and CGIs using chroma-key or rotary encoder are already available in shooting studios. However, they are limited to indoor use. Meanwhile, methods of composition for mixed reality with HMD (head mounted display) are also proposed. This system aims to realize indoor-outdoor systems to pre-visualize the movie scene with the dedicated camera for filmmaking.

Compared with conventional PreViz, our system has an advantage that users can determine camera-work intuitively by confirming composite images that utilized real backgrounds in real time at the shooting site.

In addition, our system has an advantage of higher image quality. The system visualizes not only SD level MR-PreViz images, but also HD MR-PreViz images by offline rendering using stored images in a RAID system and recorded camera motion information. Our system suggests confirming SD level MR composite images in real-time and rendering HD level MR composite images which contain the same objects with the earlier, non-real-time one.

4.4 System configuration

Here we introduce the system configuration of the MR-PreViz image capturing and compositing. The system configuration is shown in Fig. 3, and the appearance of the system is shown in Fig. 4.

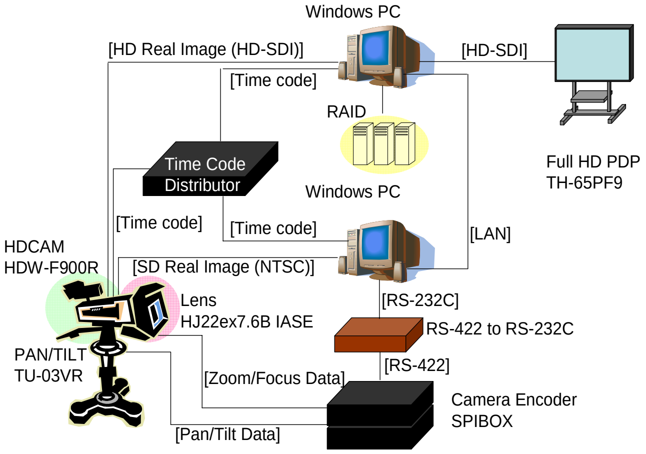

Fig.3. System configuration.

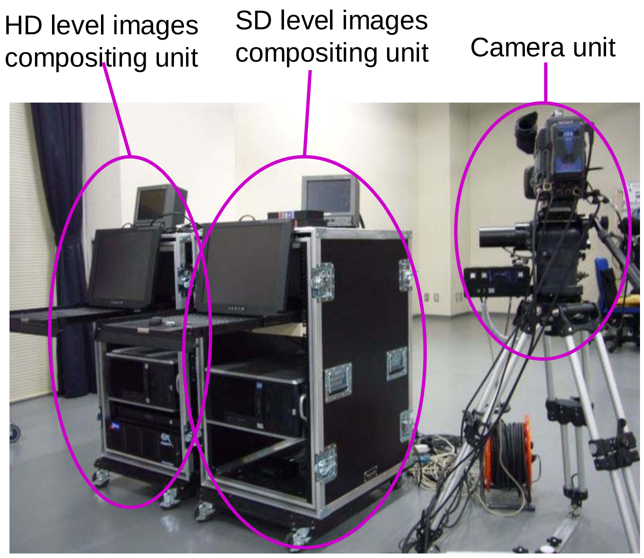

Fig.4. Aspect of MR-PreViz image capturing and compositing system.

V. MR ACTION REHEARSAL SYSTEM

5.1 Background

In the MR-PreViz project, actions are recorded and collected beforehand by using motion capture (MoCap) and 3D Video technology. This action data is edited and placed in 3D-CG space using CASCADES. CASCADES is a subsystem of the MR-PreViz that enables the reconstruction of action scenes performed by many actors by combining solo action. Edited action data is superimposed onto the real scene at MR-PreViz shooting.

We require several visualizing techniques to design and shoot the action scene as follows:

- Visualizing from an arbitrary viewpoint in 3D-CG space
- Visualizing composite images in which action data is superimposed onto the real background from an objected point of view by a camera
- Visualizing the composite images from a first-person perspective

In this research, we aim to visualize action scenes from a first-person perspective to confirm real-size action and action rehearsal. To this end, we propose the MR action rehearsal system as a subsystem of MR-PreViz.

5.2 Overview of MR action rehearsal system

This system is the MR action rehearsal system for actors who are inexperienced in fighting action. The users of the system can practice with real-size CG enemies in front of them viewed through a video see-through head mounted display. We propose a novel rehearsal method that enables one person to act correctly while confirming the other person's action. Therefore, users can confirm timing and position of their action. As a first step, we apply this method to sword fighting action. We adopt a sword device as an interactive device. The device enables collision detection and evaluation of user's action simultaneously.

5.3 Prior action consideration using recorded actions

CASCADES has the following functions to support designing an action scene intuitively and interactively.

(1) Coexistence of various types of action data

CASCADES can handle various types of action data including MoCap, 3D Video, and hand animated action data. MoCap and hand animated action are imported with the CG character model as an FBX format file by using Autodesk MotionBuilder. "3D Video" is a technology that allows one to reconstruct an image seen from any viewpoint in real time from video images taken by multiple cameras [6]. It is a kind of video-based rendering and is sometimes called "Virtualized Reality" [9]. We adopted the method developed by Kyoto University [10]. 3D Video data is inputted as polygon data and color information of every point as .x file format. Because these data types are polygon data types, the data can be drawn using OpenGL or DirectX graphics libraries. However, to handle different file types of action data, we face another

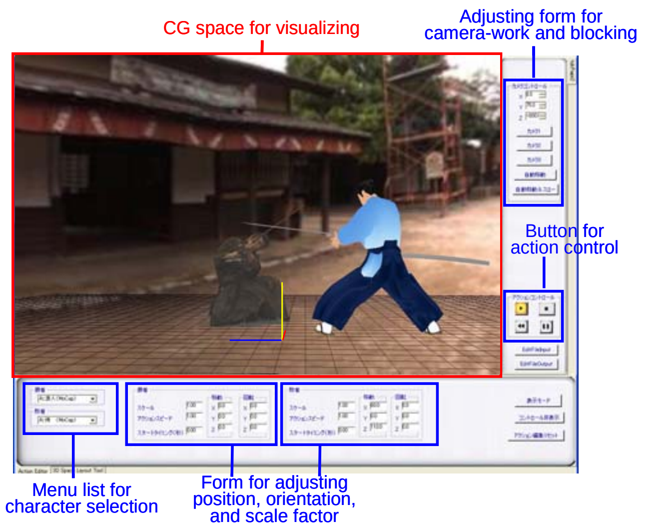

Fig. 5. Screenshot of CASCADES.

problem of the differing sampling rates. The sampling rate of current 3D Video data is lower than that of other types of motion data. We solved this problem by the nearest-neighbor approximation on the time axis.

(2) Adjustment of action data

CASCADES can arrange action data at arbitrary positions with arbitrary orientations and scale factors. These functions are manipulated by using the GUI shown in Fig. 5. The user can design action scenes interactively with arbitrary camera-work and camera blocking. CASCADES also has a function of semi-automatic adjustment for action speed and initial position of action.

5.4 Elemental technologies of the MR action rehearsal system

5.4.1 Semi-automatic adjustment for timing of action and initial position of action

To construct a sequence of action which is composed of individually recorded action data, semi-automatic adjustments are performed. Reference points which correspond appropriately with position and timing are specified spatiotemporally for optimization of initial position and timing of actions. Nowadays, head-to-head sword fighting is assumed as an action scene. The adjusting of the actor alters the timing and position to correspond with those of the reference actor. Timing is altered before adjusting the initial position.

5.4.2 Key Frame and Timing Controllable Frame

Key Frames (KF), a frame in which two characters' actions are intersected, is assigned to adjust timing. Timing Controllable Frames (TCF), frames which don't affect feeling sensitively when playing speed of action are changed, are also assigned. Finally, playing speeds in TCFs are adjusted to correspond each actor's timing of KFs. The conceptual diagram of the adjustment of timing is shown in Fig. 6.

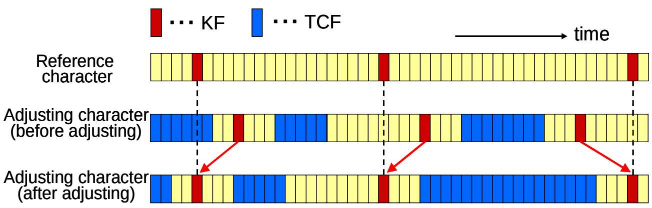

Fig. 6. Adjustment of timing.

5.4.3 Contact Point

Contact Point (CP), a position in the two characters' actions intersected in KF, is assigned to adjust the initial position of the actor. In the case of sword fighting action, CPs are the intersected points of the swords of each actor. CPs are assigned with respect to each KF. Initial positions of actions are determined so that the sum of the distinction between corresponding CPs is minimized.

5.4.4 Result of semi-automatic adjustment

The result of the semi-automatic adjustment of timing and initial position of sword fighting action is shown in Fig. 7. This shows the difference between the before and after application of the method. From these results, we can confirm that actions are successively adjusted for timing and initial position in KFs by our method.

Fig. 7. Adjustment of initial position.

Fig. 8. Screenshot of first-person's view of the action rehearsal system.

5.5 Functions of the MR action rehearsal system

The MR action rehearsal system supports practicing action by showing a life-size designed action scene in front of users through HMDs. To realize this, the system has the following functions:

(1) Displaying life-size computer generated action from first person's perspective

This is a function that displays priory captured action. Action scenes are captured using motion capture and imported into the system as FBX format. The action data are superimposed onto real background in full proportion through HMDs after adjusting position and timing by the techniques described in section 4.4. A screen shot of the first-person's view is shown in Fig. 8.

(2) Displaying MR composite image from objective view

To show users the whole image of the scene which contains them, MR composite images from an objective view are also visualized. Appearances of objects in mixed reality space are synchronized between the objective view and the subjective view by using scene graph.

(3) Interaction and feedback using an interactive device.

To increase efficiency of practice, the system enables users to interact with a CG actor. When the system detects collision between CG actors and CG objects handled by the device, vibration feedback and feedback sounds are displayed in real time.

(4) Evaluation of user's action

The system enables the users to receive evaluation of their action by utilizing the sensor's outputs, which are position and orientation of the device and the HMD. As the first stage of the evaluation of action, the system evaluates whether the users put their device on the proper point in the scene with correct timing. In other words, the system evaluates the users' action based on the distance between CPs and the position of the device in KF. A research of evaluation of a user's experience in MR space already exists [11]. This research evaluated the work in which users manipulate an instrument. In contrast, we are going to develop an evaluation method for works involving whole body motion.

5.6 System configuration

The MR action rehearsal system consists of the Canon MR Platform System [12] with the Canon VH-2002 video see-thorough HMD, the sword device attached with a Polhemus magnetic sensor, and a vibration device. The sword device detects their position by a magnetic sensor and the vibrations are controlled by RBIO. In addition to the PC for the first-person perspective, the PC for subjective view is also composed into the system. The system configuration is shown in Fig. 9. The sword device is shown in Fig. 10.

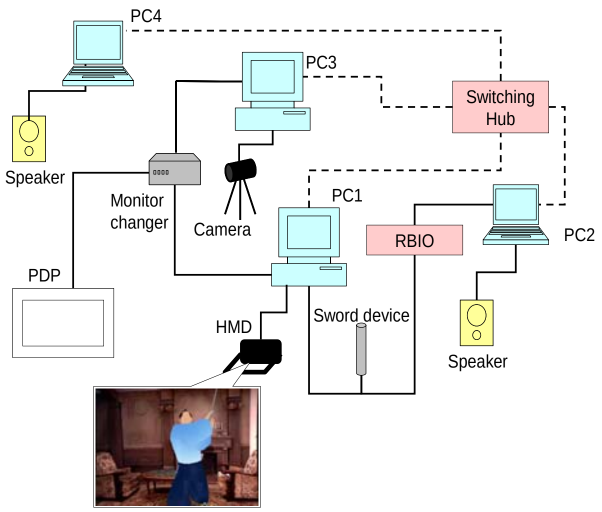

Fig. 9. System configuration of MR action rehearsal system.

Fig .10. Sword device.

VI. DEMONSTRATION OF THE SYSTEMS AT ISMAR 2007

To invite other researchers' opinions in the research field of AR/MR, we demonstrated the two subsystems described above at the 6th International Symposium on Mixed and Augmented Reality (ISMAR 2007) [13]. We organized a special demo session, "Mixed Reality Pre-Visualization for Filmmaking". We and our collaborators in the MR-PreViz project, the groups from Kyoto University and Nara Institute of Science and Technology, demonstrated developments of the research in the MR-PreViz project in this demo session. In this section, we introduce scenarios and responses of our demonstrations.

6.1 Scenario of the MR-PreViz image capturing and compositing system

We demonstrated the MR-PreViz image capturing and compositing system at the ISMAR with the following scenarios. To increase the reality of the use at the actual shooting, we assumed the demonstration place as the shooting site of kung-fu movies, and decided to construct the studio set base off of a street in Asia, such as in Hong Kong. Computer-generated kung-fu actions are superimposed onto a real background.

With this scenario, the flow of the demonstration actually experienced by users is as follows:

1. Arrangement of the camera in the demonstration space where the look is similar to that of a shooting site
2. Measuring the interior and exterior parameters of the camera
3. Superimposing animation of CG characters, whose actions are recorded and designed earlier as shown in the right image of Fig. 2, onto a real background within the system
4. Determining camera-work while confirming composite images in real-time
5. When camera-work is decided, offline rendering of HD composite images (HD MR-PreViz movies) is started
6. After the above offline rendering, the user can review the HD MR-PreViz movie

In this demonstration, we will let the audience experience 4. and 6. to understand our system.

6.2 Demonstration of the MR action rehearsal system

We also demonstrated the MR action rehearsal system as example demonstrations of visualizing action scenes from a first-person perspective. The scenario of the demonstration is as follows:

- The story of the demonstration is that the samurai, who is the hero, forces himself on the residence kept by the boss of the rascal to seek justice
- The system is demonstrated in an imitated set of an old samurai residence
- The users play the role of the hero. At first, we show them the video clip of the model action that they will use for guidance.
- The users fight against the rascal, 2 close confidents of the boss, and the boss, respectively, in 3 stages
- The action of the enemies is fixed, so the users only have to is put their sword device on the proper point of the enemies' action

(a)

(b)

Fig. 11. Appearance of MR action rehearsal system (a) The studio set. (b) MR-composite image from objective view. (See Color Plate 7)

(a)

(b)

Fig.12. Appearance of the demonstration of MR-PreViz image capturing and compositing system (a) the studio set. (b) HD level MR-composite image from the camera. (See Color Plate 8)

- If the user's sword and the enemy's sword hit each other, a sound is played and the device is vibrated
- The user's actions are evaluated according to the distance between user's sword and CPs in KFs

6.3 Results and Impacts of the demonstrations

The demonstrations successfully finished without any trouble. Appearances of the demonstrations are shown in Fig 11 and Fig 12, respectively. The MR-PreViz image capturing and compositing system is highly evaluated, especially in respect to the image quality of HD MR composite images shown in (b) of Fig 12. The MR action rehearsal system is also highly evaluated for its entertaining users' experience. These demonstrations successfully introduced the ability to apply to actual shooting because of the construction of fine studio sets shown in Fig. 11 and Fig. 12.

VII. CONCLUSIONS AND FUTURE WORKS

This paper introduces an on-set MR-based PreViz systems used in the MR-PreViz project, which aims to develop supporting systems for filmmaking by utilizing mixed reality technology. We believe that our demonstrations at ISMAR 2007 indicated the potential of the MR-PreViz while being an enjoyable experience.

For practical application, there are some limitations and problems which we have to work out.

The MR-PreViz image capturing and compositing system is limited in its movement to only panning and tilting. We have already adopted the IS-900 ultrasonic sensor to detect camera movement as 6DOF for indoor space. It is not advisable to rely on mechanical sensors when increasing the degrees of freedom of the camera-work from two to three and four. The vision-based tracking method is considered promising while considering the degree of freedom in an outdoor environment. If we can attain geometric correspondence by the vision-based tracking method [14] or some other method, a method to achieve photometric correspondence between outdoor scenes and CGIs should be devised. Even if our MR-PreViz movies are successful, the weather conditions may differ from those of the actual shoot.

An MR action rehearsal system needs to consider how best to support the actors. We plan to research visualizing methods and support features such as changing action speed adaptively. The sword device also needs improvement with the method of force feedback.

The PreViz technology cultivated throughout this project has applications other than just films. In addition, theatrical performances or live events in outdoor environments can be effectively pre-visualized and successfully simulated.

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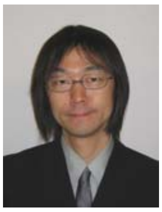

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