One-Man Movie: A System to Assist Actor Recording in a Virtual Studio

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Abstract—**Acting in a movie is not an easily accessible activity for regular people, not to mention creating a movie alone. Based on the existing functions such as directors, photographers, and editors in a virtual studio that have been established in previous work, this research aims to design a computer-assisted system in virtual reality with actor functions allowing people to experience acting and create their own Computer Graphics (CG) movie. Through virtual reality and wearable motion capture devices, our system allows a user to enter the virtual studio as an actor. The user starts by choosing the role they want to play and then completing the drama performance under the guidance of the system. The motion of the actor will be recorded and in sync with the animations of other characters adjusted in real-time. As such, in addition to playing a single role, the user can also choose to perform and record multiple roles that can be put together to form the film. Thus, the entire CG movie can be completed by a single user alone. We have implemented a prototype of such a system and conducted an experiment to evaluate the system. The results will be reported in this paper.**

Keywords- one-man movie, virtual studio, virtual reality, assistive interface, acting recording

I. INTRODUCTION

Filmmaking requires many professions and talents to be put together to produce a good movie. The roles in a movie production team may include screenwriter, director, cinematographer, editor as well as actors. As computer technologies evolve, the tools used in the production process also advance. In particular, as Virtual Reality (VR) technologies become prevalent in recent years, more companies are adopting VR techniques to assist movie production. In addition, in recent years, people start to use VR to develop systems for filmmaking training and entertainment. Such systems enable regular users to play the abovementioned roles in a movie production team, which are not easily accessible in the real life. In previous work [9], researchers have developed a VR system allowing a user to play the role of director, photographer, and editor. However, it is a challenge to design a system to allow a user to play as actors in VR at different times and produce a Computer Graphics (CG) movie all by herself.

In this paper, we will describe a novel system designed to achieve the goal of allowing a user to participate as actors for multiple roles in a CG film. In other words, based on the previously developed functions for creating a virtual film set, we are adding another component of actor toward the goal of making a *one-man movie* [5], where the whole CG movie can be created by a single user. To enable the actor functions, we will make use of popular VR devices as well as a low-cost Motion Caption (Mocap) device [16] to create an environment that can be easily accessed by regular users. In addition, we will design assistive user interfaces to guide the user to act properly and adopt motion editing techniques to allow other actors played by the computer, or Non-player Characters (NPCs) in the game terminology, to act correspondingly according to the player's action.

The rest of the paper will be organized as follows. We will describe the work related to our research in the next section. Then, we will describe the core desired functions of our system and how we have designed and implemented them. Next, we will demonstrate the functions and interfaces in our system. In the fifth section, we will present the experiment that we have conducted to evaluate our system. Finally, we will end the paper with concluding remarks and future research directions.

II. RELATED WORK

The system proposed in the paper involves technologies and applications in VR, virtual film sets, and motion editing for generating synchronized animations for NPCs.

A. Virtual Reality in Filmmaking Applications

The VR and computer animation techniques have been widely used in many applications such as education and various kinds of training [2][8][10][14][15]. Among the potential applications, filmmaking with VR is an emerging one becoming popular in recent years. In the film production process, many special effects or non-existing characters are added with post-processing after the shots are taken. Typically, the actors need to perform in front of monochromatic green or blue screens with hardly any cue to the digital scenery that is supposed to surround them. To facilitate the actor to get familiar with non-existing characters or virtual scenes and perform in either a rehearsal or live performance, a VR system was designed and evaluated in the work by Bouville, et al. [3]. The experimental results showed that the system could achieve the same training effect and the users preferred VR training to classic training.

Besides, Slater et al. [17] have also proposed to use the concept of Shared Virtual Environment (SVE) to design a VR system to help the director and actors perceive non-existing scenes and immerse into the story during rehearsal such that a more successful live performance afterward can be achieved. Similarly, SVE has been used in the work of

Normand et al. [13] for the actors and the director, located remotely to perform rehearsal with a full-body interactive virtual reality system that can track and transmit full-body motion data through the network in real-time.

B. Virtual Film Set

In addition to being used as a tool for filmmaking, VR can also be used in training, entertaining, or film production for CG movies. Lin et al. [9] have proposed a VR system allowing a user to play different roles, such as director, photographer, and editor, in a virtual film set. Several cinematographic functions such as shot recommendation, dynamic camera tracking, etc. have also been developed to emulate the functions that a virtual film set can provide. The concept of *One Man Movie* was proposed in the work by Galvane et al. [5]. In the proposed system, in addition to the three roles mentioned above, they attempt to enable the crafting of film sequences for users with no prior knowledge in 3D animation in such a way that the user can also pose the actors (virtual characters) directly in the virtual environment. Although intuitive, posing virtual characters is tedious and resulting animation may not be natural.

C. Motion Capture and Editing for Virtual Characters

Motion generation for virtual characters has been a challenging research topic for many years partly because human motion is complex but well familiar. There exist many ways to generate character animations, including keyframe methods, procedural methods, and data-driven methods. Min et al. [12] have proposed a deformable motion model allowing the users to specify desired motions through a simple user interface. Coros et al. [4] has proposed a generalized dynamics and control model that can generate walking-related motions with results robust from disturbance or different humanoid parameters.

Motion editing usually refers to the techniques to compose or adjust motion clips to form a new motion without changing the patterns or characteristics of the original motions. In the early days when motion capture data became available, Witkin et al. [19] have proposed the concept of motion warping aiming at adjusting motion clips by time or animation parameters to satisfy different environmental constraints. Hsu et al. [5] also have proposed a method to edit a motion according to guided time-warping to generate more natural motions.

No matter how the motions are generated, it is important to be able to specify the constraints of the motion concerning the environment including other characters in an interaction scenario. Procedural animation approaches usually can take this kind of constraint into account in addition to the high-level parameters used to specify the motions. For example, VHML proposed by Marriott et al. [11] and STEP by Huang et al. [7] are two scripting languages that can be used to define dependency constraints required in an interactive scenario such as dialogs. In addition, an early work by Allen [1] has already defined the thirteen relations between event intervals allowing users to specify the constraints of multimedia elements.

III. CORE FUNCTIONS DESIGN AND IMPLEMENTATION

In this work, we aim to design a novel application to allow a user to participate as an actor in a CG movie. We assume that the screenplay of the movie and the models of the virtual characters are all ready. What a user needs to do is act in a given scene with other characters in the play according to the play script. To allow a user to act in such a virtual movie, we need to be able to record the gesture and voice of the actor while playing corresponding animations of other characters. Therefore, as shown in Fig. 1, several functions are desirable in realizing such a system.
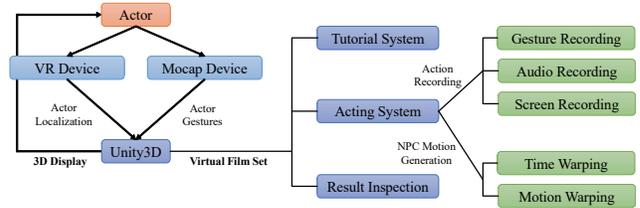

Fig. 1. System architecture

For example, we will need to have an animation scripting language to describe the relations and constraints between the actions among all actors involved in a scene. We will also need to be able to capture the whole-body movements and duplicate the motions on a player avatar in real-time in the VR system. To engage the user in the actions, we will need to prompt and guide the user with a proper user interface. When the user is in action, the opposite actor played by the computer should react to the player's actions in a synchronized and precise manner. The system should also be able to recognize the end of a player's action to finish a shot or to trigger a following action that may be initiated by the opposite actor. When a user has finished the acting of a scene, he or she should be able to examine the result by displaying the animations from the viewpoints of a cameraman. Besides, to allow the user to get familiar with the user interface as well as how to interact with the system, we have also designed a tutorial subsystem for the user to practice before the real play.

In our system, we have used the Unity3D engine as our development platform and adopted HTC VIVE Head-Mounted Display (HMD) as well as hand controllers to interact with the virtual environment. In addition, we have used Perception Neuron [16] wearable motion caption device to capture the motion of the user during the performance. In the following subsections, we will describe how we have designed the scripting language, how the motions of the opposite NPC actor are modified in real-time to be in sync with the player's action, and how the user interfaces are designed to help the user select and engage in the play of a scene.

A. Adopting and Extending a Scripting Language

Unlike a regular screenplay with loose structure, the script for the computer to perform needs to be precise. There has been research about designing extensible scripting languages to specify computer animations with constraints.

In this work, we have adopted and extended the Behavior Markup Language (BML)[18] to define our screenplay. An example of BML, as shown in Fig. 2, consists of two behaviors in sequence with a synchronization constraint. The example play that we have used for our experiment is a short clip reproduced for the movie "Back to the Future." For our demonstration purpose, we have extended the BML language to contain more behavior tags such as drink, walk, eat, sweep, and idle, in addition to the existing speech, gaze, and gesture behavior.
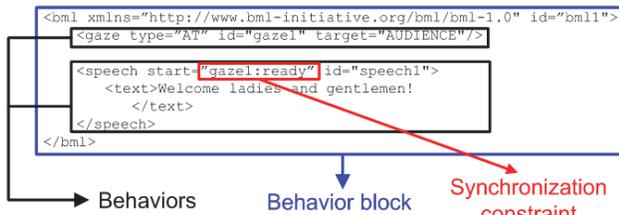

Fig. 2. An example of BML

An example of the extended BML is shown in Fig. 3, which describes the following scene:

- <eat> Marty stared at George, who was eating at the counter. (Both start at the beginning of the scene: start="0")

- <gesture> George became annoyed and finished eating by putting the bowl down.

- <gesture><gaze> George showed a frustrated gesture and turned to Marty.

- <speech>: George finally said "What?"

- <speech> Marty then speak out "You're George McFly!" (constrained by George's speech)

Fig. 3. An example of the extended BML

B. Recognizing the End of a User Action

To allow live performance with the opposite actor, we need to recognize when a user action ends to show the corresponding animations according to the script defined in the previous subsection. Therefore, we extended the scripting language to specify how to recognize the end of a user behavior. Currently, we have included three ending conditions as described below.

- Depending on others: There exist many situations that the end of a user action depends on the end of an action performed by the opposite actor. For example, when an actor is listening to the other actor's speech, the listening behavior ends when the other actor stops talking.

- Depending on voice volume: If the actor is taking a lead in speaking, the end of the behavior can be recognized by the point when the actor finished his lines or the volume of the speech vanishes.

- Depending on the stop of a gesture: If the actor is giving a gesture, the behavior ends when the gesture stops. Therefore, we can recognize the end of an action when the body motion stops.

C. Animation Time Warping

Since it is difficult to control the speed of user actions, there always exists the problem of synchronizing the actions of two actors. Real actors can synchronize their actions through tacit understanding. However, the opposite actor (NPC) played by the computer needs to adjust the animation according to the user's action in real-time. For example, if the user action ends earlier, the NPC will need to speed up the action in a reasonable range. If the user action is delayed, the NPC can either slow down his animation with time warping or fill in an idle motion for an appropriate duration. For example, in the left of Fig. 4, assume the action a of actor A, followed by action d, is delayed for some time. Action d needs to be synchronized with the end of action b (by actor B), which triggers action c. Then, the NPC (actor B) can slow down the animation of action b by time warping to synchronize with action d. Similarly, on the right of Fig. 4, one can also fill in additional idle animation (instead of being still) for actor B if action a by actor A is delayed.
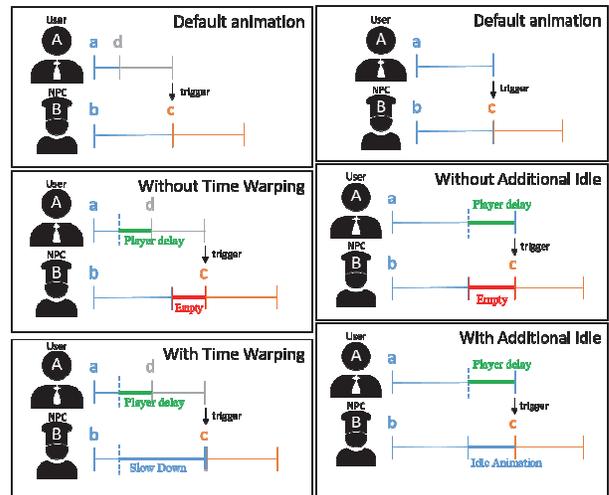

Fig. 4. Synchronizing actions with time warping

The aforementioned methods, especially for time warping, are appropriate only if the time differences are in a

reasonable range. Otherwise, the director (system) will call a "cut," let the user know the problem and ask him to do it again at a proper pace.

D. Motion Warping

In addition to the synchronization of actions, actors may need to adjust their motions to achieve their common goal, especially when the actors are having physical interactions and need to coordinate with each other. For example, in the example scene shown in Fig. 5, Lou is handing a broom over to Goldie. If the user is playing as Lou and may move to any location in the scene, it would be odd for Goldie, played by NPC, to miss the broom during the hand-over, as shown on the left figure of Fig. 5. In other words, the computer should compute a proper location for Goldie to reach the broom more easily. Goldie also needs to receive the broom with an appropriate posture such that one of his hands can reach the broom. Similarly, if the user plays the role of Goldie, the computer needs to compute a good location for Lou to hand the broom to Goldie. To achieve this goal, the system needs to modify the prepared canned motions by motion warping to walk to the desired location and by adjusting the head orientation and computing the hand posture with inverse kinematics.

Fig. 5. Coordination without (left) and with (right) motion warping

Besides, we can use similar techniques to adjust all recorded motions for coordination. For example, after the motions for all roles have been recorded, we can examine the motions recorded at any instances from a cameraman's view. Since they are recorded at different times, there is no guarantee that the motions will be in sync. Therefore, we can apply the same techniques as in the live performance to adjust the motion of any one role to respond to the motion of the opposite actor.

In the demonstrative scene, there are objects that the actors need to interact with such as a purse, a dinnerware, and a bicycle. The interaction is specified through the extended BML, and the system will compute appropriate NPC motions to handle these objects or the objects will automatically fit into the hand of the actor when a grasp action is issued.

IV. DESIGN OF FUNCTIONS AND USER INTERFACE

Since the application of experiencing as an actor is novel, it is desirable to design intuitive and assistive user interfaces to help the user perform as an actor. According to the different stages of the acting process, we have designed various types of interfaces to facilitate the user in cooperating with the system. The stages of the process include acting preparation, formal acting and recording, and result examination. The user interfaces designed for these stages are described in the following subsections.

A. The Acting Preparation Stage

Before the acting starts, the user needs to make a few decisions to set up the scene properly. For example, the user can choose the actor that he would like to play with the laser pointer function provided by the controller as shown in Fig. 6.
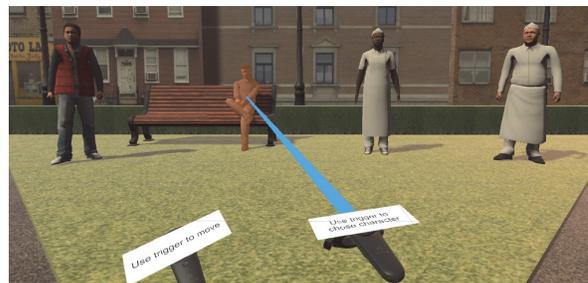

Fig. 6. User interface for actor selection

Besides, to allow the user to choose the segment of the scene that the user would like to act, we have designed a panel interface for the user to select as shown in Fig. 7. On the panel, the user can use the buttons of the controller to switch through different parts of the scene. When a part is focused, the default animations of the actors for that part will be displayed for the user to preview the desired acts in the given part of the screenplay. Note that the actor that the user plays will be shown in translucent to hint the user about the role.

Fig. 7. User interface for segment selection

After selecting the role and segment to play, the motion capture device is worn and calibrated. Then, the system is ready for the user to start acting. As shown in Fig. 8, after the user puts on the headset, the user can now see his own hands and body through the actor avatar. The system will guide the user to put down the controller and move to the default location of the actor to get ready for acting. The user has to pose himself according to the shown translucent figures, shown in the upper-right figure. When each part of the user body is in position, that part of the translucent figure will turn opaque (lower left figure). When all parts of the body are in position, the count down for acting will start by showing a clapperboard (lower right figure).
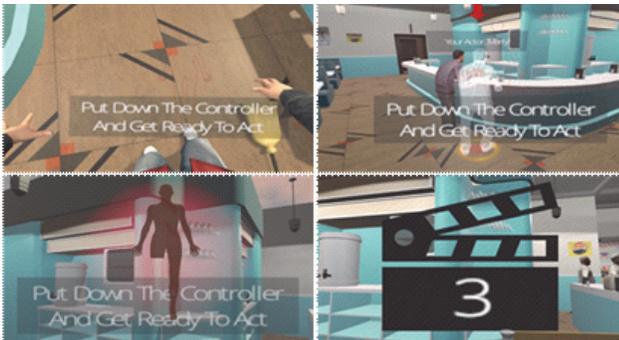

Fig. 8. User interface for segment selection

B. The Acting and Recording Stage

In the acting and recording stage, the system will start to record what the actor performs and speaks till the end of the part is reached. Then, the system will assume that the user will continue to act for the subsequent part by default such that the mood of the user can extend to the next part without interruption. However, the user can choose to stop voluntarily and restart the next part later at any time. When the recording of the motions and voice ends, the data will be saved to external files with names consisting of the actor name, part id, and time such that the user can retrieve any recordings by their file names in the future.

As shown in Fig. 9, during the acting stage, the user can see the name of the part he is acting as well as a progress bar showing the current status of the act. Besides, as the play progresses, the system will give textual hints to the user about the lines that will be read out by the actors including the ones, by the NPC (colored in white). The lines are split into two parts, including the current line used in the dialogue and the next line to be read out next. To distinguish from the current line, a translucent color will be used for the next line. This allows the user to read ahead and prepare for the next act.

Fig. 9. Textual hints to assist user in performing an act

C. The Result Examination Stage

After the user has finished acting and recording, he can immediately examine the result through a camera view. By using a laser beam via the controller, one can select any recorded result from a hierarchical list of menus to find a specific recording. The menu is organized by actor name, part number, and time. When the user uses the laser beam to point at a specific item, the system shows the preview of the recording of that item on a screen (as shown at the lower-right corner of Fig. 10) to help the user to find the clip they want to use.
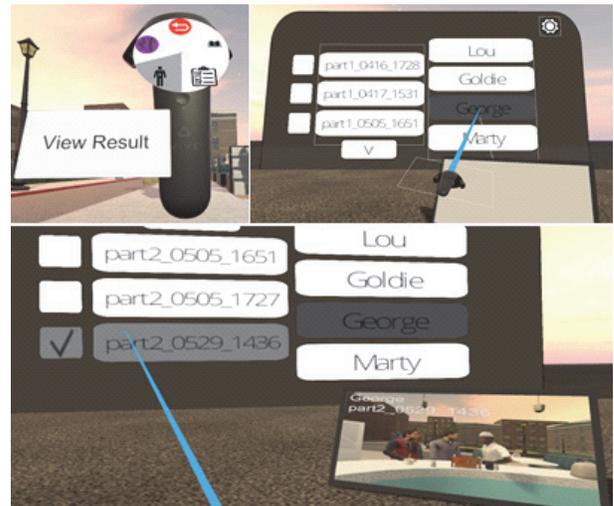

Fig. 10. Examining the result by pointing on the menu to preview

In addition to examining a specific recording for an actor, one can also pick the recordings for more than one actor and examine the result at the same time. For example, for the same part of a scene where two actors: Marty and George are

shaking their hands, one can check out any of the recordings for both actors, respectively. Then, the animations for both actors will be played at the same time as shown in Fig. 11. However, since there is no guarantee that the two selected recordings will be in sync, we will use the same time warping and motion warping techniques used in Section III to produce proper animations for coordination motions.
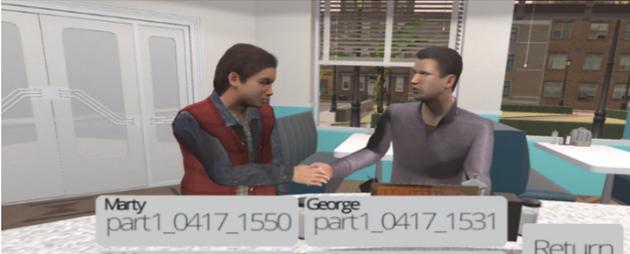

Fig. 11. Examining animation result with coordination motions from two independent recordings

V. SYSTEM EVALUATION

To evaluate the system that we have proposed and see if the design goals of the system have been achieved, we have conducted an experiment to obtain user feedback. We have invited fourteen users with various experiences in using VR and wearable mocap devices to participate in the study. The ages of the subjects range from 20 to 26, and only two of them have not experienced VR before. Regarding the mocap device, five of them have only heard of the technology, four have seen other people using it, while five of them have used it before. Among the participants, only one considers himself being familiar with acting.

Fig. 12. Experimental procedure

The procedure of our experiment is depicted in Fig. 12. We first described the basic ideas and operations of our system to the participants and showed them the movie clip used in our experiment such that they could understand the story background and screenplay. Then we helped the participants wear the VR and mocap devices and performed a proper calibration. The participants then started a tutorial session to use the functions in our system to accomplish a task. After the participants knew how to operate the system, a formal acting session would start by giving the participants tasks in two scenes. In the first scene, Marty and George were having a conversation. The participants were asked to play as Marty and George separately and tried different speeds of acting according to instructions. In the second scene, the participants acted as Lou and Goldie alternatively to experience how to hand over a broom to the actor

previously played by themselves. After the participants finished the required tasks, they can have more practice at their own will. Finally, the participants were asked to fill in a questionnaire about their experiences in using the system, and in-depth interviews were conducted to obtain more feedback.

The survey questionnaire consists of 24 questions in four groups including basic operations, assistive user interfaces for acting, result examination, and overall evaluation. All questions were answered in the form of a 5-point Likert scale with 1 to 5 indicating the degree of agreement with the statement (most disagree (1) to most agree (5)).

Table I shows the questions about basic operations with the system and their average scores (Mean) and standard deviations (Stdev) from the survey. One can find that the designs of most basic operations are intuitive. Among all operations, the selection of an actor gets the highest score while the interface for choosing a recording to examine receives the lowest score. Besides, the last three questions (5-7) have higher standard deviations than the others, which means that there exist higher discrepancies among users. We also found that one of the participants forgot how to examine the recorded results and gave a lower score to the last question.

TABLE I. SURVEY OF BASIC OPERATIONS

Questions	Mean	Stdev
1. The operation on the menu of the controller is intuitive.	4.00	0.76
2. The textual introduction beside the menu button is helpful.	4.43	0.73
3. The way of selecting an actor is intuitive.	4.71	0.45
4. The way of selecting a part to act is intuitive.	4.21	0.77
5. Starting an act with a specific pose is intuitive.	3.93	1.10
6. Raising a hand to cut an act is intuitive.	4.00	1.07
7. The interface for examining the result is intuitive.	3.79	1.15

In Table II, the survey results of our assistive user interface for acting reveal that the functions we design to help the participants perform acting are useful in general, especially for functions of graphical guide for initial posing, captioning, and interacting with an actor played by the user himself earlier. However, the scores for some functions are a bit lower than we expected. For example, the progress indicator function for acting is not as helpful as expected probably because most novice participants focused more on acting and reading out the lines and did not pay attention to the progress bar.

TABLE II. SURVEY OF ASSISTIVE USER INTERFACE FOR ACTING

Questions	Mean	Stdev
8. The graphical guide for initial posing is helpful.	4.57	0.49
9. Using captions for reading lines is helpful.	4.64	0.61
10. The hints about the part in a scene and progress are helpful.	3.86	1.06
11. When doing Task I, I can notice that the NPC actor moves according to my speed of motion.	4.21	0.77
12. When doing Task I, I think how the NPC actor coordinates with me is proper and effective.	4.00	0.76

Questions	Mean	Stdev
13. When doing Task II, I can notice that the NPC actor coordinates with my acting.	4.14	1.06
14. When doing Task II, I think how the NPC actor coordinate with me is proper and effective.	3.93	1.03
15. Interacting with an actor that I played previously is interesting.	4.79	0.56

Table III shows the evaluation of the result examination functions. The scores for all four questions are above 4.0. Functions such as being able to view the acting from a cameraman's viewpoint right after the performance and having a preview screen to assist in selecting a recording are all considered useful. The most highly valued function is the one allowing the user to see how any two performances recorded separately can be put together to make the final film.

TABLE III.   SURVEY OF RESULT EXAMINATION

Questions	Mean	Stdev
16. One can view the result directly after the performance is convenient.	4.21	0.56
17. Clearing the film set when examining the result makes the viewing simple and clear.	4.07	0.80
18. The preview screen in the result examination interface is helpful.	4.21	1.01
19. Being able to select to view the results of two actors all by myself is interesting.	4.79	0.41

The survey result for the overall system is shown in Table IV. The questions are about the usability and satisfaction of the system. The results show that although the system is not difficult to learn, it is not as intuitive and easy to use as desired. Given the number of novel functions and the unfamiliarity with the virtual environment, participants mentioned in the interview that it was not difficult to learn individual functions but it was easy to forget learned functions. Besides, probably because the system cannot record facial animation yet, some participants did not consider it proper for the system to serve as a formal training system for acting skills. However, the participants pointed out that the system provides a good opportunity for experiencing acting and is excellent for entertaining, especially for the function of allowing two separated recordings to be played together. Some participants even used this function to create funny and creative film clips.

TABLE IV.   SURVEY OF THE OVERALL SYSTEM EVALUATION

Questions	Mean	Stdev
20. The system is handy and easy to learn.	4.00	0.93
21. The system is simple and easy to use.	3.64	0.81
22. The system makes me feel that I am actually acting.	4.00	0.93
23. I will recommend this system to others for experiencing acting.	4.21	0.77
24. I will recommend this system to others for practicing acting skills.	3.86	0.99

From the survey questionnaire and interview with the participants, we find that most participants agree that most of the designs of our system were appropriate to assist them in performing the functions at various stages of the application. The system has novel functions, for example, the graphical guide for initial posing and the captioning function to read out the lines, used to help a novice user learn how to act in such a virtual setting. Besides, thanks to the time-warping and motion-warping techniques developed in our system, the user can interact in sync with another actor played by the computer. The motion of the actor can even be the one recorded by the user himself earlier. It is also interesting to see how any two recordings for different actors can be put together to form the final film clip.

VI. CONCLUSIONS AND FUTURE WORK

As an effort in realizing the "one-man movie" goal in a virtual studio, we have designed a novel virtual reality application allowing a user to play multiple roles as actors at different times for a Computer Graphics film. In our system, the user uses wearable VR and mocap devices to act and interact with the virtual environment including other actors. With proper annotation of constraints in a structured drama script, we use time warping and motion warping techniques to modify the motion of the opposite actor in real-time to interact with the actor played by the user. We have implemented such a system with a demonstrative scene and conducted an experiment to evaluate such a system. Most of the feedback from the participants is positive and encouraging. However, we also find that the value of such a system is more toward creative entertainment instead of professional training, which may shed some light on the future direction of such a system.

Although there exist applications of mocap for movie production, we believe that we are the first to use low-cost wearable devices to create a novel application of acting for creating a personalized film. However, we also believe that there is still much room for improvement. For example, the user interfaces used to select a part in a scene and to retrieve a recorded motion clip may be made more intuitive. The system may also be further extended to include the recording of facial expressions to produce a full-fledged animation. One may also expect to develop more entertaining or game functions such as selecting different acting styles to take different degrees of challenges. In addition, if the system can be connected with the network, we can also develop applications for more than one actor or even audience to have a live performance.

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