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Automatic Motion Capture System of Actors' Body Movements with Action Cueing

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Abstract -The body movement of an actor is one of the important factors in theatrical performance. In theatrical practice, a director instructs actors about such important element. In addition to practice with the whole members, actors practice individually to check and review the director's instructions. Therefore, to keep a record of practice is important to improve the quality of performances. Currently, the recording of practice is done mainly in the form of writing to the script by text, but it is sometimes hard to record the body movements accurately. Therefore, we constructed a system aimed at automatic motion capture of actors' body movements in theatrical practice with action cueing. By notifying the timing of performance for an actor using smart watch, our system can record the physical expression while supporting the actors' practice. We conducted an experiment to evaluate the efficiency of this system. From the results, we confirmed that this system can record the body movements with a small workload and short time.

Keywords: motion capture, theatrical performance, body movement, smart watch, action cueing

1 INTRODUCTION

Theatrical performances are created by directors, actors and other many staffs. In theatrical performance practice, the director instructs actors about performances. Theater organizations practice many times to make the performances better. However, many theatrical organizations have problems of lack of practice places and opportunities [1]. Therefore they encourage actors' self-practicing to improve the quality of performances. In self-practice, actors mainly review the director's instructions and prepare for the roles by reading the script for the next practice. Therefore, keeping a record of practice is very important to improve the quality of the performance. Currently, the recording of practice is done mainly in the form of writing to the script by text, but it is difficult to record the body movements of actors by text. We focus motion capture technology as a method to record body movement to deal with this difficulty. However, using motion capture in a limited practice time may be a heavy burden for the director and decrease practice time.

In this paper, we construct a system aimed at automatic recording of actors' body movements in theatrical practice while supporting actors' learning. In recording practice, it is difficult to grasp the timings of actors' performances. To deal with this problem, we utilize action cues for supporting theatrical practice. We assume that action cues are not only useful for supporting theatrical practice but also for grasp timings of actors' performances. By automating recording body movements of actors', it is unnecessary to devote time for motion capture separately from the practice time, and it is possible to reduce the workload of recording body movements.

In order to evaluate user's workload of this system, we conduct experiments in two situations: recording by this system and by a human-shaped input device. In both situations, the subjects participate as the director and record the physical expression of actors. Two experimenters participate as actors. In the experiments, we compared workload and time required to record actors' body movements. From the results of the experiments, we confirmed that this system can record body movements by lower workload and shorter time. The rest of this paper is organized follows: Section 2 describes overview of theater activities. Section 3 introduces Digital-Script, and Section 4 describes related works. Then, the detail of our system is described in Section 5, Section 6 shows evaluation of this system. Finally, we conclude in Section 7.

2 THEATER ACTIVITIES

This section describes the outline of theatrical practice and the methods of recording practice.

2.1 Outline of Theatrical Practice

In Japan, theater activities are performed by many organizations continually since early time, and it is recognized as an important artistic activity. When performing theaters in public, a theater organization completes the work while practicing repeatedly many times. A director's role by the process of the practice is to coach actors to bring their performance close to ideal. On the other hand, actors try to understand the director's intention and express it in the performance. Steps of a practice are roughly divided in three, "Reading Scripts", "Standing Practice", and "Stage Rehearsal" [2]. According to Goan et al., in these practice steps, "Timing of each action", "Body movements", and "Feelings" are important [3]. A director mainly instructs actors about these important elements during practice.

- Timing of each actions

Timing of the start of a line creates a span between lines. Different from a picture work such as movies, spans are transmitted to the audience in real time. Spans are the time the audience uses imagination about the kind of relationship between characters. Therefore, spans are very important element being concerned with success or failure of performances [4]. In actual practice, instructions from a director to an actor about spans are the most frequent. A director coaches actors about it very finely. As an example, "a little early", "immediately begin to say when the line of that person is finished", "open for two seconds." are given. By taking the appropriate spans, performances become better, and it is possible to avoid lines become monotonous.

- Body movements

The actors express the feelings of the roles playing with their own bodies. Frequently, the director instructs the actor how to move in order to express the feelings of the role. Also, it is a very important factor how the actors look like from the audience. Therefore, actors often check their movements with a mirror.

- Feelings

Feelings in performances are expressions and perceptions that actors feel. An actor must speak lines with getting into the character. When the remark of actors is not enough of feelings, it is given a worthless performance. Therefore, directors coach for actors about feelings frequently. The grounds of remark of actors are feelings that the character has.

2.2 Methods of Recording Practice

Many theatrical organizations lack of places to practice and opportunities, therefore they encourage actors' self-practicing to improve the quality of performance. In self-practice, actors mainly review the previous lesson and prepare for the role by reading the script for the next lesson. Therefore, it is important to keep a record of these elements to improve the quality of the performance. The following methods can be considered for recording performance.

- Writing to the script by text

Recording is done by handwriting. Currently, this is the most common recording method. This method is difficult to record nonverbal elements such as body movement. In addition, there is a disadvantage that an actor must temporarily stop the performance to record.

- Movie

In this method, it is possible to record a lot of information and record nonverbal elements. Indeed, there are many actors to use for review by taking movies of their own acting. However, the recorded movie has no use other than watching it. In addition, there is a disadvantage that confirmation becomes complicated in proportion to the recording time. For example, if you record a two hour lesson by a video, it is hard work to find a few seconds of acting that you would like to check.

- Motion capture

This method is suitable for recording non-verbal elements such as body movements. Also, recorded data can be applied to various things. For example, it is possible to visualize a recorded motion data and confirm the performance from an arbitrary viewpoint. In addition, if you record the performance separately for each actor, it is possible to easily search for performance that the actor wants to confirm. On the other hand, there is a disadvantage that cost of motion capture equipment is high, and in some cases, additional time is required for motion capture.

Considering the use of the record of physical expression for practice, we think that high versatility of recorded data is important. According to research [5] by Ando et al., to improve actors' quality of performance, it is important for actors to review performance from an objective point of view. Take motion capture as an example, you can check the movement of your body from any viewpoint based on the data obtained by motion capture. Furthermore, it is possible to apply motion to avatar using that data, and various application methods using motion capture are conceivable. On the other hand, in the case of a movie, since the direction is fixed, it is impossible to confirm the viewpoint from the audience seats and opponent actors. Therefore, we focused on motion capture in this paper. In the next chapter, we introduce Digital-Script that handles elements necessary for theater as digital data.

3 DIGITAL-SCRIPT

3.1 Overview of Digital-Script

We propose Digital-Script which is added with the data necessary to performances. Digital-Script is handled as a database, and is different from the conventional scripts.

Theatrical production has technical elements and actor's performance elements. Technical factors are such as sound effect, lighting effect, stage carpenter and stage design. In actor's performance, “Timing of each actions”, “Body Movements”, and “Feelings” are very important elements. However, it is difficult to read these factors from a script written only in text. Therefore, in order to visualize these important elements, we try to handle them as digital data. Especially, in this paper, we focus on adding motion capture data of actor's body movements to Digital-Script. Upon making database of scripts, we compose Digital-Script by text and numerical value in order to make the system which has a variety methods of the visualization to each needs, such as voluntary exercise of actors, directions input of a director, and stage confirmation. In addition, in order to help actors grasp the timing of each action that changes on the stage, we add time information to each data. These data are added in the input applications of the digital script of the previous research. In this paper, we add motion data to Digital-Script.

3.2 Digital-Script Database

Digital-Script is handled as database which is implemented by MySQL. Figure 1 shows the configuration of the Digital-Script database. Digital-Script is distributed by scene unit. Scene data manages a certain scene and includes “SceneID”, “Title”, “SceneName”, and Actor data. In the following, we explain Actor data in detail. In Actor data, the peculiar ID and name are assigned to every character. In addition, “SAY”, ”FEELING”, ”MOVE”, ”SEE”, and “ACTION” are included in it.

- SAY

SAY data are about actors’ speech. This means that an actor speaks A when the elapsed time gets t sec. Strength means that an actor should strongly/weakly read an appointed part of lines A. Long means that an actor say lines A in l second.

- FEELING

FEELING data are about the feelings of an actor. This means that an actor has feelings E at the time of t second.

- MOVE

MOVE data are about actor’s standing position. This means actor’s movement to (x, y, z) coordinates during elapsed time between t1 sec to t2 second.

- SEE

SEE data are about actor’s head direction where the actor should look at. This means that the actor looks at the designated direction when the elapsed time get t sec. The direction where the actor should look at is designated by (x, y, z) coordinates.

- ACTION

ACTION data are about actors’ body movements. This means that the actor performances as M when the elapsed time get t second.

The above data can be used in various applications. Section 4.3 describes examples in which these Digital-Script data are read into the system and visualized. In this paper, ACTION is newly defined in Digital-Script and motion capture data is added to it.

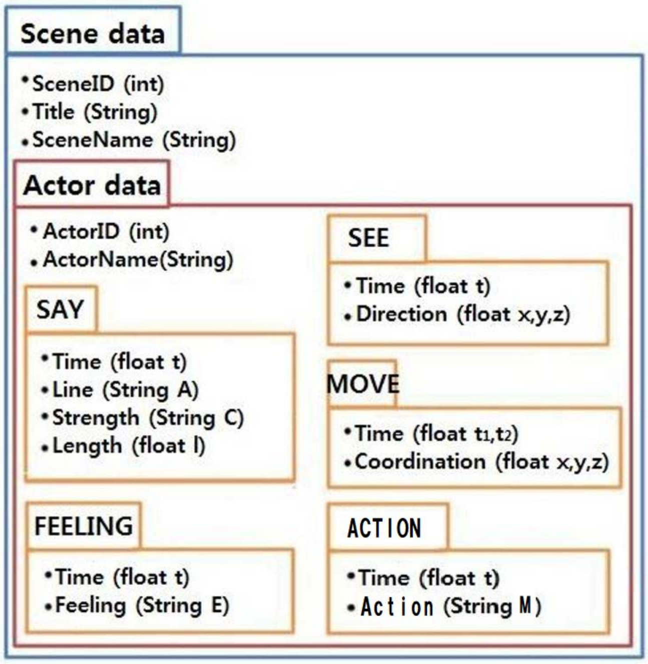

Figure1: Components of Digital-Script Database

4 RELATED WORK

In this section, we introduce several studies to support theatrical activities.

4.1 Recording of Body Movements

Hachimura et al. tried to motion capture the behavior of Japanese dance, which is a traditional Japanese art, to make it useful for inheritance and preservation [6]. In addition, Hachimura and colleagues analyze the characteristics of "Okuri" which is the basic behavior of dancing by using motion-captured data. There are also many studies using motion capture in the field of ballet and dance. Saga and colleagues have studied using motion capture for simulation of ballet choreography [7]. Their study's goal is to develop an automatic composing system for ballet by using motion Data archives. However, these studies use large-scale equipment for motion capture, and Hachimura also states that the operation of these equipments requires experts with special skills.

4.2 Action Cueing

Takatsu et al. applied smart watch to support the practice of dramas [8]. In order to practice smoothly, it is important for the actors to learn the correct order of performance. However, in the early steps of practice, it is difficult for actors because a play script has a lot of information to learn. In this research, Smart watch has the role of telling the information to the actors and informing them in the correct order. Smart watch is a way to convey information without putting a physical burden on the actor. This research makes it easier for actors to perform in the proper order, and actors can concentrate more on acting.

4.3 Digital-Script

We introduce two studies to support practice of theater by using Digital-Script.

Shimada et al. proposes the self-practice system [9] which reflected a direction of a director. This focuses on timing of an action such as beginning of lines and movements. This system visualizes Digital-Script in two ways like Fig. 2. In this display, timing of each action is showed by a time-line and spatial information is showed by 3DCG. By using this system, it is possible for an actor to practice while grasping progress of a performance intuitively.

Theater organizations may not practice anytime with all members because they don’t have their own practice space and most actors have another job. By using Digital-Script, theatrical practice support system [10] enables actors to practice performance in the situation that a director or a part of actors cannot participate. This system needs monocular Head Mounted Display (HMD). In this HMD, virtual actor that plays absent actor’s role is displayed, and a user is coached automatically by detecting and comparing actor’s movement with information in Digital-Script like Fig. 3.

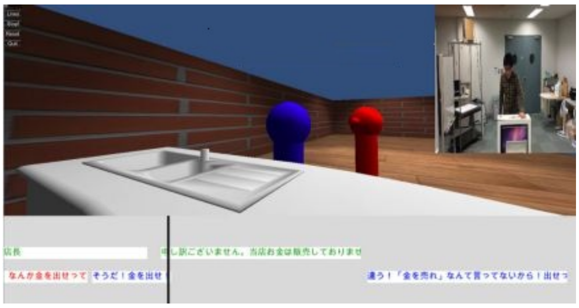

Figure 2: Voluntary practice system [9]

Figure 3: Theatrical practice support system [10]

5 AUTOMATIC MOTION CAPTURE SYSTEM OF ACTORS' BODY MOVEMENTS

Recording performance is important in the practice of theaters. However, with the current method, in practice of acting, recording body movements is sometimes hard. Therefore, we propose the system that can automatically record actors' body movements while supporting for actors' learning. This system can notify action cueing to actors during recording body movements. This automatically generates motion data without long time and heavy workload. By notifying action cue to actors, it can make practice smooth and reduce mistakes of acting. The contributions of this system are as followings.

- Simplification of recording body movement

By automation of the recording of the actors' physical expressions, there is no need to perform additional work for recording. This system does not require special skills or more time than practice time. This contribution can solve the problem that the recording operation shortens the practice time.

- Data acquisition of body movement as Digital-Script

Scripts are what represent story of the theater. However, since scripts are written in text, actors cannot intuitively grasp the non-verbal elements such as the movement of the body and the standing positions of the actors. Therefore, we propose the motion capture system for the physical expressions of actors. We treat this recorded motion data as a part of Digital-Script and save it in a format that can be used for various purposes.

- Notifying of the order of performance of actors

In this system, smart watch notifies the order of performance of each actor individually. Smart watch shows what the actor will do next and the next line. Smart watch's vibration informs the order of acting, so the actor does not need to see the screen. By using this system in the early stage of practice, the actor can learn the flow of acting by notifying action order. This system can automatically record the body movement while actors concentrate on performance.

5.1 System Overview

This system automatically records the performance without a heavy burden for an actor or a director. Also, this system notifies actors of the order of acting and supports the practice of actors. Figure 4 shows the usage of this system. This system requires PC, Kinect, tablets, and smart watches. The director uses the web application on the PC. The Fig. 5 shows the screen of the web application. On the right side of this screen, the result of reference to Digital-Script database is displayed. Lines, timings, actor's names, actions are shown. The director checks the performance of the actors while confirming the flow of the script on this screen. By pressing the start button, practice begins along the data of Digital-Script. On the left side of this screen, the director can select the line and resume practice from there. Also, the director can delete or add lines on this application. All the results of editing are automatically saved in Digital-Script.

When the performance starts, this system tracks progress of performance automatically according to Digital-Script, and notification is sent to the actor's smart watch. At that time, all movements of actors are motion captured by Kinect and saved as Digital-Script. On the other hand, the actor wears a smart watch and practices. The smart watch notifies by vibrating according to the behavior of each actor and the timing of speech. This timing of notification is based on the Digital-Script database.

Figure 6 shows the notification display of smart watch. On the display of smart watch, the line that the actor speaks at that timing is displayed. Therefore, actors can reduce mistakes in acting and can practice smoothly. This function plays the role of "prompter" in an actual theater that gives a reminder to actors who forgot the line etc.

We use Samsung Gear Live for smart watch. Samsung Gear Live is designed to be used in paired with an Android tablet, and an Android tablet is required for communication with the server of this system. Figure 7 shows the display of Nexsus 7, and this is the interface that cooperates with PC and smart watches. You can grasp the status of the connection with PC and smart watches, and the status of this system on this screen.

Figure 4: Usage image of this system

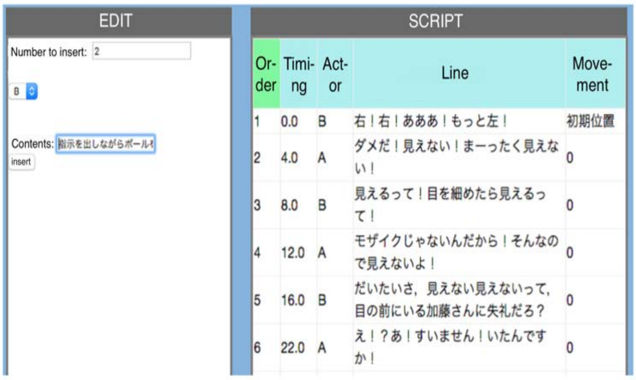

Figure 5: Web application

Figure 6: Notification window of smart watch

Figure 7: Tablet display

5.2 Use Case

We assume that this system is used in the following cases.

- Early stages of practice

This system is supposed to be used at the stage of practice. In early stage of practice, actors do not remember the order of acting perfectly. Normally, at this stage, the actors practice while having a script, and receive instruction from the director.

- 4 meters square space

This is the extent of space where actors can practice while moving. This range of space depends on specifications of Kinect.

- Participating of the director in practice

We assume that the director participates in the practice and instructs the actors' acting. The director has the right to decide all performance. Therefore, we assume that theatrical organizations use this system with the aim of recording of performance.

5.3 Implementation

Figure 8 shows the hardware architecture of this system. This system requires PC, Kinect, tablets, smart watches. We used Samsung Gear Live for smart watches and Nexsus 7 for Tablets. Samsung Gear Live is connected to the PC server by WebSocket. In order to connect quickly and support multiple devices, we use WebSocket. WebSocket can keep socket open with bidirectional connection and support stable connection in multi device environment. This was implemented by node.js and was connected to the device using Cloud9 and heroku. In this system, each actor wears this smart watch and receives action cueing by vibration. Samsung Gear Live is paired with a Nexus 7 tablet. Since only one smart watch can be controlled with one tablet, we used multiple tablets connected by Bluetooth. We use Android Wear 5.0.1 as the implementation platform and the Android Java API v21.1.2. The processor is 1.2 GHz Qualcomm Snapdragon 400, and the display is Super AMOLED 1.63 type. Tablet OS is Android Wear 4.4.3, 1.3 GHz NVIDIA Tegra 3 mobile processor. Kinect for Windows API v2.0 was used as a depth camera to recognize the movement of each actor. Kinect has a depth camera, RGB camera, multiple eye ray microphone, and processor. Kinect can recognize the gesture, the position, and height of the users. Figure 9 shows summary of the network configuration of this system.

5.4 Motion Capture

In a theatrical practice, multiple actors participate it. Since this system can detect up to six actors, it is possible to record movements of multiple actors at the same time. This system always detects actors during practice. Then, motion capture is started automatically when action cue is notified to the actor. After the start of motion capture, skeleton coord inates of the actor are recorded for each joint for few seconds. The recorded data is output as a CSV file and finally converted to a Digital-Script format. Figure 10 shows an example of visualized Digital-Script data.

6 EVALUATION

This chapter describes experiment to evaluate workload of this system in recording actor’s body movements.

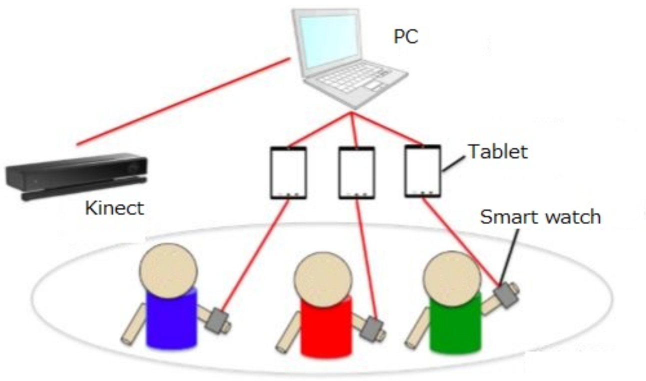

Figure 8: Hardware architecture

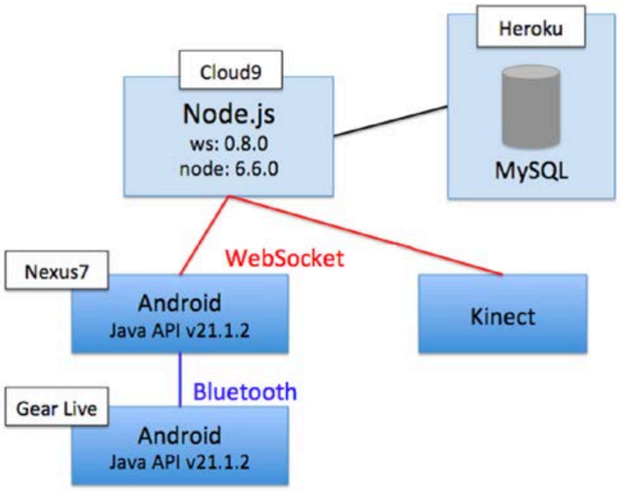

Figure 9: Network configuration

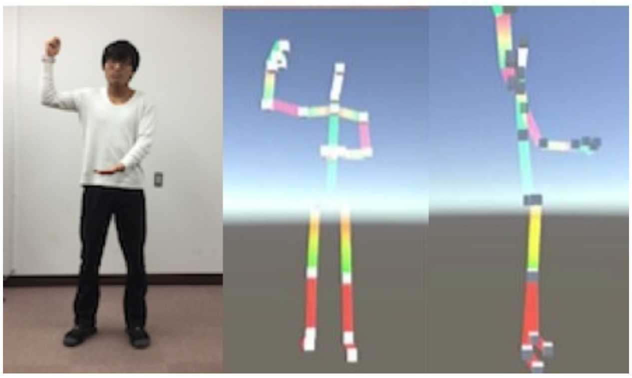

Figure 10: Visualized image

6.1 Subjects

10 university and graduate school students participated in this experiment. One subject participated in one experiment.

6.2 Method

As a director, the subject instructed the actors about performances while watching the script. Two experimenters participated in the experiments as the actors. Subjects recorded performances of actors. We conducted the experiment in two situations: Experiment A and B. In Experiment A, subjects recorded body movements of actors with this system, and in Experiment B, subjects record it with human-shaped device. Five of the ten subjects belonged to Group 1. Firstly, Group 1 participated in Experiment A and then did Experiment B. The remaining 5 subjects belonged to group 2. Group 2 first participated in Experiment B and then did Experiment A.

In Experiment A, the subject participated in this Experiment As a director. First, the subject saw the performance of the actor. Subsequently, the subject instructed the acting of the actors. The content of the instruction was what the experimenters informed the subject in advance. After those instructions, the actors performed acting according to instructions. The subject recorded their performance using this system. We measured the time required to record performance. To summarize, Experiment A proceeded in the following procedure.

1. Explanation of the flow of the Experiment and the operation of this system
2. Watching practice
3. Instructing to the actors
4. Recording practice

In Experiment B, like Experiment A, the subject participated in this experiment as a director. The subsequent flow is the same as Experiment A, but in this experiment this system was not used. First, the subject saw the performance of the actor. Subsequently, the subject instructed the acting of the actors. After those instructions, the actors performed acting according to instructions. We recorded that situation in video. The subject created motion data using QUMARION (see Fig. 11) while referring the video. QUMARION is a human type input device developed and sold by Celsys [11], Inc. It is a device used for creating motion and pose of 3D animation. The size of this device is 29 × 30.8 × 10.8 (cm) and the weight is 255g. It has 16 joints and 32 sensors and can create motion intuitively and easily. We measured the time required by subjects to make motion using this device. To summarize, Experiment B proceeded in the following procedure.

1. Explanation of the flow of the experiment and the operation of this system
2. Watching practice
3. Instructing to the actors
4. Practice with recording by video
5. Creating motion data by QUMARION with reference to movie

We used a script for each experiment. We used two scripts, X and Y, from free script download service [12]. Details of the two scripts are shown in the table 1. Both scripts are for a theater of around 150 seconds. For both scripts, we prepared six experimental tasks.

6.3 Evaluation Items

In both experiments, we evaluated the workload and required time in the recording of the physical expression of the actors.

Figure 11: QUMARION [11]

Table 1: Details of scripts

	Length	Number of lines	Number of tasks
Script X	150 sec	30	6
Script Y	150 sec	32	6

To evaluate workload of with this system, we used NASA - Task Load Index (NASA-TLX, here in after referred to as TLX). TLX is one of the most frequently used subjective workload metrics. TLX has 6 scales: Mental Demand, Physical Demand, Temporal Demand, Overall Performance Frustration Level. They are rated for each task within a 100-points range with 5-point steps. Figure 12 shows part of the answer sheet for these scales. Subjects fill in this line the degree of involvement in the workload for each scale. We measure the position of the mark on the line to get a rating of 1 to 100 ($=\nu_i$). We create an individual weighting of these scales by letting the subjects compare them pair-wise based on their perceived importance. This needs subjects to choose which scale is more relevant to workload. The number of times each is chosen is the weighted score ($=\omega_i$). We calculated WWL (weighted workload) from this weighted score by formula (1). A small WWL value means that the participant's workload is small.

$$\mathrm{WWL} = \frac{\sum_{i=1}^{6} (\omega_i \times \nu_i)}{\sum_{i=1}^{6} \omega_i} \tag{1}$$

In Experiment A, we measured the time taken for recording of the physical expressions of the actors. On the other hand, in Experiment B, we measured the time taken to create motion data by QUMARION.

6.4 Results and Discussion

Table 2 shows group 1's result about 6 scales of NASA-TLX, and table 3 shows group 2's. Table 4 shows the results

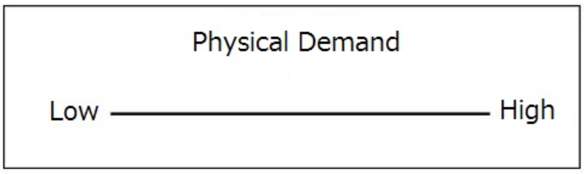

Figure 12: Workload metrics

Table 2: Result of NASA-TLX for group 1

Scale	Proposal method	Compared method
	Score	
Physical demand	27.4	49.4
Mental demand	36.6	43.6
Temporal demand	40.2	18.2
Performance	33.8	57.6
Effort	16.5	62.8
Frustration	27.2	52.2
WWL (Weighted workload)	33.8	56.5

Table 3: Result of NASA-TLX for group2

Scale	Proposal method	Compared method
	Score	
Physical demand	33.2	59.6
Mental demand	37.8	59.8
Temporal demand	15.8	18.2
Performance	84.3	47.2
Effort	36.2	38.2
Frustration	34.0	43.8
WWL (Weighted workload)	38.3	51.1

Table 4: Workload of group 1

Experiment	Script	WWL(Weighted workload)
A	X	33.8
B	Y	56.5

Table 5: Workload of group 2

Experiment	Script	WWL(Weighted workload)
A	X	38.3
B	Y	51.1

Table 6: Results of time required

Experiment	Group 1	Group 2	Ave.
A	223.4 sec	195.2 sec	209.3 sec
B	827.2 sec	626.0 sec	726.6 sec

for group 1's workload, and Table 5 shows group 2's. Table 6 summarizes the results on the time required for each group of experiments.

From table 4 and 5, it can be seen that the values of WWL are smaller in Experiment A in both groups. From this, we found that this system can record actors' body movements with low workload.

From table 6, we see that the time taken by Experiment A is shorter. From this result, it can be said that subjects record body movements with this system by the shorter time. We assume that one of the reasons for reducing workload is shorter time required.

From table 1 and 6, we found that Experiment A takes about 209 seconds compared with the time of the scripts of

150 seconds. The time required by this system is slightly longer than the script time, but we think that recording can be completed in a sufficiently short time.

7 CONCLUSION

Self-practice of actors is encouraged by many theater organizations. In a self-practice, an actor reviews important elements in performance such as body movements. Therefore, during practice, to record instructions about it from the director is very important to blush up actor’s performance. Currently, the recording is done mainly by writing text in a script. However, this method is not suitable for recording actors' body movements and it is hard for an actor to review during self-practice. Therefore, we tried using motion capture to deal with this problem. Generally, motion capture requires long time and workload. In this paper, we propose the system that simplifying records body movements during practice by motion capture. In addition, by notifying the actor of the action cue using the smart watch, this system reduces mistakes in performance of actors and makes practice smoother. We conducted experiments to evaluate the workload of this system and time required. To evaluate workload of with this system, we used NASA-TLX. TLX is one of the most frequently used subjective workload metrics. As a result, we confirmed that the system can record in short time with small workload.

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