A System for Supporting Performers in Stuffed Suits

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Abstract. Stuffed suits have been widely used at various events. However, performances with stuffed suits present two main difficulties in that performers are not aware of their postures because of the difference in the shape and size of the stuffed suits and the physical human body, and it is difficult for them to communicate smoothly with others because of limited visibility. These problems lead performers to train excessively to acquire a high degree of skill in performances. The main goal of our study was to construct a system to support performers in stuffed suits, which would enable them to act like the characters they represented. From the results we obtained from evaluating our prototype system, we confirmed that our method could effectively support performers in stuffed suits.

Keywords: Stuffed suits, HMD, Support.

1 Introduction

Stuffed suits are widely used at various theme parks and events because performances with them are popular with all ages, and it makes audiences smile and be happy. Performers in stuffed suits need to represent the characters they portray because they have to play the role of making characters in the virtual world appear in the real world. Posture and communication with others are the most important elements for them to portray characters credibly. However, performers in stuffed suits encounter two main difficulties: (1) they are unaware of their posture because of the difference in the shape and size of the stuffed suits and the physical human body, and (2) there is a difficulty in communicating smoothly with others because of limited visibility. In addition, since performers often gain visibility from parts other than the eyes of the character, they cannot look around by gazing when in stuffed suits. Therefore, they also cannot naturally communicate with others. To overcome these problems, performers have to train very hard to acquire high levels of skill in performances.

On the other hands, there has been many studies on user support with wearable computing technologies, such as Skinput [1] and A Haptic Wristwatch [2]. A user in wearable computing environments wears a computer, sensors, and actuators. Using this equipment, the computer knows the context of the user and provides various services in response to this context.

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The goal of our study is to construct a system to support performers in stuffed suits, which will enable them to act like the characters the stuffed suits are meant to represent. The problems above occur because performers in stuffed suits cannot deal with them like they do with their own physical human bodies. Our system has two main functions to provide a sense of embodiment to the stuffed suits of performers, which support posing and enhance visibility. The results from evaluation indicated that our system could effectively support performers in stuffed suits. In addition, we actually used our proposed system at several events and confirmed that it was effective.

The remainder of this paper is organized as follows. Section 2 outlines related work. Section 3 describes the design of our system and Section 4 explains its implementation. Section 5 describes evaluation of the system and discusses the results. Section 6 describes actual use of the system, and Section 7 presents our conclusion and plans for future work.

2 Related Work

In the field of motion analysis, there have been researches on reconstructing the motion of an actor with a wearable system of outward-looking cameras [3], and on analyzing motions, such as the turns a snowboarder makes with GPS and a gyroscope attached to the snowboard [4]. In addition, Corinne *et al.* proposed a system that recognized upper body gestures by using strain sensors [5]. However, there have been no studies on supporting behaviors that have taken into consideration the difference in size between the actual body and stuffed suits.

In efforts to assist human visibility with cameras, there has been a system that displays images taken with a camera attached to the rear of a car [6]. Koeda *et al.* proposed a rescue assistance system to teleoperate an unmanned helicopter where the pilot could watch the images from cameras on the helicopter with a head mounted display (HMD) [7]. However, there have been no studies on assisting the human visibility that have taken into account the problems with wearing stuffed suits.

Some attempts with HMD have been made with research, to support users using wearable computing technologies. Stochasticks [8] is a practical application of wearable computing and augmented reality, which enhances billiards. The system in this research recognizes the position of the billiard table and the billiard balls, and displays an auxiliary line on HMD. Ikeda *et al.* evaluated the usefulness of providing information with HMD in interactive performances using a projector [9]. The Wearable MC System [10] enables a master of ceremonies (MC) to run events smoothly. An MC using this system can see scripts and instructions from the director with HMD. There have been many studies to support users using HMD with these systems and the usefulness of information presented with HMD was confirmed in each study. However, there have been no studies on supporting performers in stuffed suits with HMD.

Fig. 1. Preliminary study

In research using wearable computing technologies in the field of entertainment, Tomibayashi *et al.* proposed Wearable DJ System [11]. This system enabled disk jockeys to perform DJ techniques by operating intuitive gestures using wearable acceleration sensors. A Wearable Musical Instrument by Dancing [12] could control performances by recognizing the steps of dancers in two phases on the basis of the characteristics obtained from an experiment on movement and sound.

3 System Design

3.1 Preliminary Study

We did a preliminary study to clarify problems when wearing stuffed suits, as shown in Figure 1. The first author of this paper wore the stuffed suit, which was designed for this study, and he made contact with people on the street for about two hours per day for five days. The details on the stuffed suit we used for this study are described in Section 5.

Even though the author could gain visibility from the nose of the stuffed suit, his field of view was restricted. This meant that he did not recognize children who came close to him and he had to turn the nose of stuffed suit toward them to see their faces. Moreover, he hit a wall in a narrow space and hit the face of stuffed suit against people while communicating with them since he could not clearly recognize his surroundings. In addition, there were problems in that he did not know what a pose to make and he did not know weather poses he assumed were a match for the character of stuffed suit.

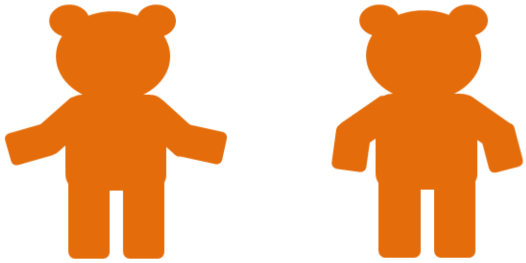

Fig. 2. Difference in impression caused by posing

From the results of this preliminary study, we confirmed that support from performers wearing stuffed suits was important because it was difficult for them to perform like characters without having much experience.

3.2 Requirements

Our system helped performers wearing stuffed suits to perform like the characters they played, focusing on posing and communication. Figure 2 shows an example of the importance of posing. Different poses in the figure evoke different impressions of the character; the left of the figure creates a friendly impression while the right of the figure creates a powerful impression. If a performer in the stuffed suit of a cute character had posed like that at the right of the figure, people surrounding him would feel strange about the stuffed suit. In addition, communication between the performer and others is an important element that improves the impression of stuffed suits. If a performer in stuffed suit had acted unnaturally such as not looking at his/her respondent's face on shaking hands, it would have created a bad impression for others around them. From these considerations, we posed three problems from the constraints on conventional stuffed suits to be solved by our proposed system.

1. Performers cannot identify their postures because the shape and the size of stuffed suits differ from those of the physical human body.
2. It is difficult to smoothly communicate with others because of limited visibility.
3. Performers usually gain visibility from parts away from the eyes of stuffed suits, and it is difficult for them to communicate by eye contact.

Problem 1 causes difficulty in posing, and Problems 2 and 3 cause difficulty in communicating with others. To solve these problems, our system has two functions, i. e., support for poses support and enhanced visibility. The former

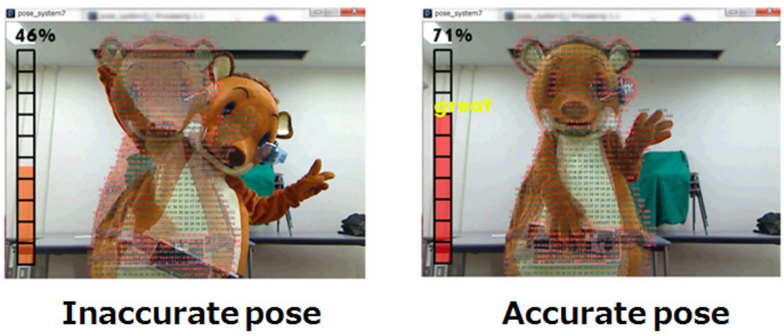

Fig. 3. Snapshots on HMD with the proposed method

supports performers to recognize how close their poses are to the correct ones. The latter enable them to gain the visibility from the positions of cameras attached to the eyes and around the face of stuffed suits.

3.3 Support for Poses

The function to provide support for poses enables performers to watch themselves objectively and to know how close their poses are to the correct ones. Current images from a stuffed suit are taken by a camera placed outside and are displayed on the HMD the performer wore. In addition to current images, our system displayed target pose images that the performer should mimic. Our system calculates the difference between the images from actual poses and the target pose, and displays the parts that are different from the target pose. More concretely, it shows the images in red for incorrect parts and in green for correct parts, and a gauge on the left indicates the rate of agreement on how much the pose of the performer matches the target pose.

Performers recognize their poses objectively from these functions and can pose easily. The left of Figure 3 only indicates 46% accuracy because the actual pose is far from the target pose, and the right of the figure indicates 71% accuracy because the angle of the body and the position of the hands are correct. Even if performers have little experience, they can pose easily with this function.

The system calculates the differences in scores for hue, saturation, and brightness between each pixel of the current image and the target image, according to the following equation.

$$\text{Score} = \sqrt{10\times(\text{hue})^2 + (\text{saturation})^2 + (\text{brightness})^2}$$

The hue value is 10 times due to its importance. Calculated scores are averaged in each area of 10×10 pixels and correct/incorrect are determined for each area according to a threshold set in advance.

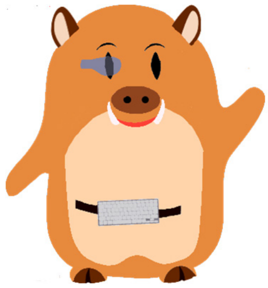

Fig. 4. An example of stuffed suit whose head is combined with the body

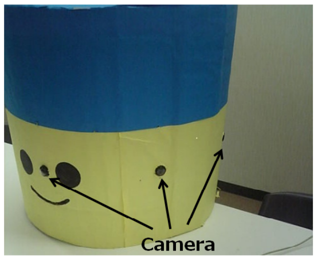

Fig. 5. Cameras around the head

3.4 Enhanced Visibility

It is difficult for performers with stuffed suits to smoothly communicate with others because of limited visibility. Especially when wearing stuffed suits where the head is attached to the body, as shown in Figure 4, performers must move their whole body to check the surroundings because they cannot only move the head. Moreover, performers often gain visibility from parts away from the eyes of stuffed suits, such as holes in the nose or mouth. This causes unnatural communication including mismatched gazing. To solve these problems, we propose a function that enhances visibility.

Performers can see the images from cameras attached to the eyes and multiple cameras around the face on the eye level of stuffed suits by wearing an HMD with this function, as shown in Figure 5. Two electromagnetic compasses are attached to the head of the performer and the body of the stuffed suit. The system recognizes the relative direction of the performer's head against that of the stuffed suit from the difference between the two compasses, and it changes the camera to be used to display images on the HMD according to the relative direction.

This function enables performers to check their surroundings easily and quickly react to the actions of people surrounding them. They can act naturally since performers can see the images from the eye level of stuffed suits. In addition, there is a possibility that a performer will gain the sensation that the size of his/her head is becoming similar to that of the stuffed suit by switching cameras according to the direction of the performer's face. We intend to evaluate this sensation in future work.

3.5 System Structure

Figure 6 shows the system structure, which consists of an HMD, a PC, cameras, and two electromagnetic compasses. An HMD and an electromagnetic compass are attached to the head of the performer and a PC is placed on his/her back. Multiple cameras and an electromagnetic compass for the function of enhanced

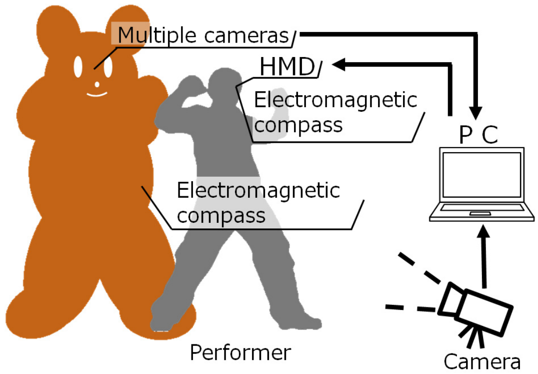

Fig. 6. System structure

visibility are attached to the head and the body of the stuffed suit. There is a camera outside for the function of supporting poses.

4 Implementation

We implemented the two prototypes shown in Figure 7. The head of the stuffed suit in Figure 7(a) is mainly made of foam polystyrene and the other parts are made of polyurethane. A helmet with an HMD is attached inside the head and a camera is attached inside the left eye of the suit. The width of the head, the body, the length of the leg, and the total height are 56, 71, 57, and 210 cm, respectively. Performers gain visibility from the nose of the stuffed suit, whose shape is elliptical and whose width/height are 15/8 cm, as shown in Figure 8(a). This means that visibility is restricted and dim because the nose is covered with mesh. The stuffed suit shown in Figure 7(b) is mainly made of containerboard. Multiple cameras are attached around the head. The width of the head, the body, the length of the arm, the leg, and the total height are 47, 64, 78, 54, and 190 cm, respectively. Performers gain the visibility from the mouth of stuffed suit, whose shape is arced and whose width/height is 10/0.7 cm, as shown in Figure 8(b). The performers' visibility is very restricted. The head is combined with the body.

The devices used for the function to enhance visibility are multiple cameras, two electromagnetic compasses, an A/D converter, and a microprocessor (Arduino nano). Arduino [13] is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. The difference in the values of the two electromagnetic compasses attached to the head of the performer and the body of the stuffed suit is sent to Arduino. It control the relay according to the value and the signal from the camera connected to the relay is transmitted to the PC. The A/D converter then converts the analog signals from the camera into digital.

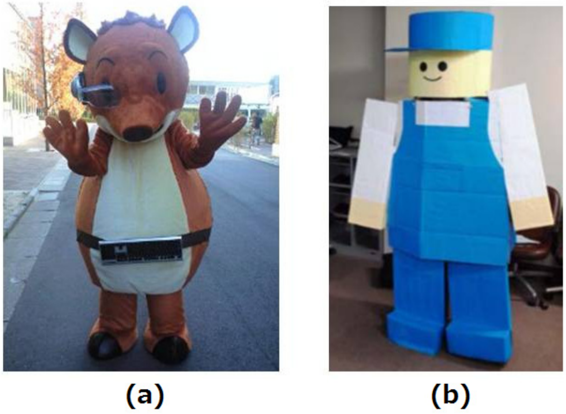

Fig. 7. Prototypes

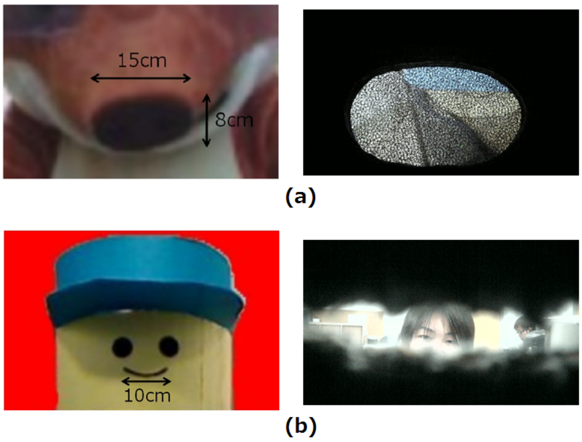

Fig. 8. Visibility for each stuffed suit

We used a Fujitsu FMV-BIBLO MG/G73 computer, whose platform was Windows 7 for the PC, a Shimadzu DataGlass3/A for the HMD, and a Sparkfun electronics HMC6352 for the electromagnetic compass. We used a Logicool Qcam Orbit for the camera outside to provide the function to support posing and a back-up camera for the function to enhance visibility. We implemented the prototype system using Processing [14].

5 Evaluation

5.1 Evaluation of Support for Posing

To evaluate the function to support posing, 10 test subjects wore stuffed suits, as shown in Figure 7(a), and posed in three ways:

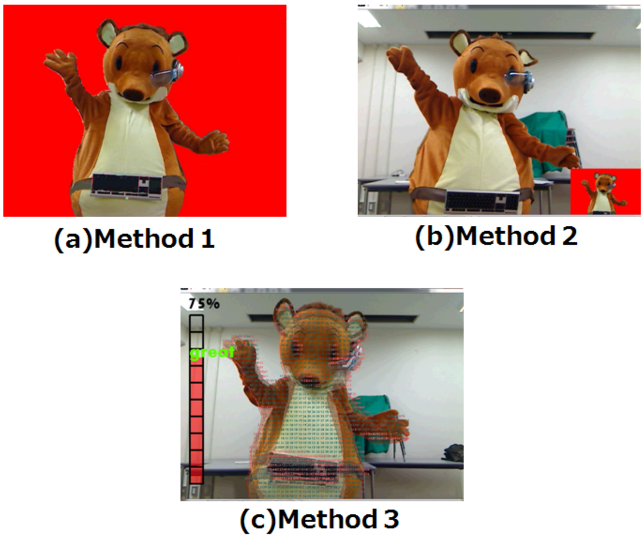

Fig. 9. Snapshots displayed on HMD

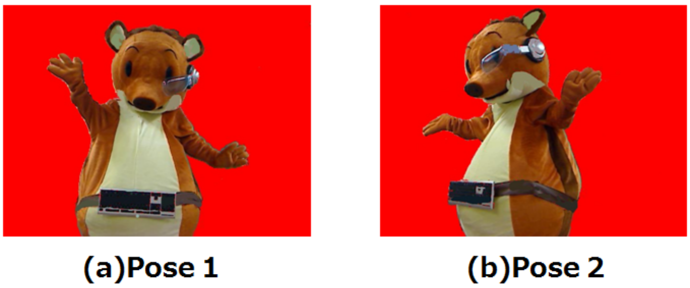

Fig. 10. Target poses

Method 1: Subjects pose looking at the target image shown in Figure 9(a).
Method 2: Subjects pose looking at the target image and the real image taken by the outside camera show in Figure 9(b)
Method 3: Subjects pose using our method shown in Figure 9(c).

Subjects made two poses, as shown in Figure 10(a), where the direction of the body faced the camera, and Figure 10(b), where the direction of the body faced to the left obliquely to the camera. Participants practiced the procedure using another pose before this evaluation. We subjectively evaluated the accuracy of posing by using five levels (5: exactly the same as the target pose – 1: entirely different from the target pose) for four elements: the right arm, the left arm, the head, and the direction of the body and recorded the total score. In addition, we evaluated smoothness when posing by measuring the time from when the pose began to when it ended and subjects answered a questionnaire on the ease of

Table 1. Accuracy of posing

	Method 1	Method 2	Method 3
Pose1	12.8	15.4	17.2
Pose2	11.5	14.2	16.8

Table 2. Average time required to take pose

	Method 1	Method 2	Method 3
Pose 1	7.33 sec	14.36 sec	24.63 sec
Pose 2	10.03 sec	17.61 sec	30.09 sec

Table 3. Easiness of taking accurate pose

	Method 1	Method 2	Method 3
Average score	1.6	3.6	4.2

making accurate poses for the three methods on the five levels (5: it was very easy to pose accurately – 1: it was very difficult to pose accurately).

Table 1 summarizes the results for the accuracy of posing. Method 3 achieved the highest scores for both poses in accuracy. As a result of one-way ANOVA of the scores for accuracy, there were significant differences (Pose 1: f value=16.93, $p<0.01$, and Pose 2: f value=24.41, $p<0.01$). From multiple comparisons for each pose using Tukey's test, there were significant differences in Pose 1 between Methods 1 and 3 (t value=-5.80, $p<0.05$) and there were no significant differences between Methods 2 and 3 (t value=-2.43, $p>0.05$). For Pose 2, there were significant differences between Methods 3 and 1, 2 (Method 1, 3: t value=-6.70, $p<0.05$, Method 2, 3: t value=-3.43, $p<0.05$). We confirmed that our proposed function of providing support for posing was effective. Moreover, there is a possibility that our method will become more effective as the difficulty of posing increases from the results of two poses.

Table 2 lists the results for smoothness of posing. Method 1 took the shortest time and Method 2 took shorter than Method 3. We considered that it took a long time to make poses because subjects tried to match the details by checking their poses. Subjects also had to stand in predetermined positions because standing position of them was very important to match their poses to the target pose when using Method 3. We considered that it took them longer to make poses in Method 3 because they had to look for the predetermined position.

Table 3 summarizes the results for ease of making accurate poses. Method 3 achieved the highest score. As a result of one-way ANOVA for the score of smoothness, there were significant differences (f value=27.20, $p<0.01$). From multiple comparisons using Tukey's test, there were significant differences between Methods 1 and 3 (t value=-5.41, $p<0.05$), Methods 2 and 3 (t value=-7.04, $p<0.05$), and there were no significant differences between Methods 2 and 3 (t value=-1.63, $p>0.05$). We considered that the difference in scores between

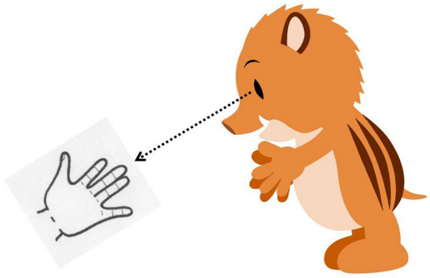

Fig. 11. Action to move the gaze to the hand

Methods 2 and 3 was small because subjects had to look for the standing position to match their poses to the target pose in Method 3.

Throughout, We confirmed that performers tended to make the accurate poses more easily by watching themselves objectively and they posed more accurately by using the function to support posing. However, performers had to stand in predetermined positions when using the function to support posing. To solve this problem, we need to improve the function to be able to determine the accuracy of posing by using other approaches such as modifying the target image dynamically and using an accelerometer to acquire a user's posture.

5.2 Evaluation of Enhanced Visibility

Five test subjects made four actions that enabled the function of enhanced visibility to be evaluated.

Action 1: A subject turns his/her head in the direction that his/her communication partner in front of his/her is pointing. Then, he/she also point to the communication partner. The height of the hand position is the same as that of the height of the partner's eye. After three actions, he/she answers a questionnaire on the ease of understanding the action of his/her partner (5: he/she can understand it without unnatural actions such as looking for his/her partner's finger – 1: he/she cannot understand what was happening) and the ease of making actions (5: he/she can move his/her hand naturally – 1: he/she cannot move his/her hand to the appropriate position).

Action 2: As seen in Figure 11, the subject moves his/her gaze of the stuffed suit to the position of the hand of his/her partner. The partner moves three positions of his/her hand at random. The subject makes the above action once for each place and answers the questionnaire on the ease of moving his/her gaze of the stuffed suits to the exact position (5: he/she can move the gaze of the stuffed suits smoothly – 1: he/she cannot move it smoothly at all).

Action 3: A subject avoids an obstacle placed at the eye level of the stuffed suit. An aluminum can, whose height was 17 cm and width was 7 cm, as shown in

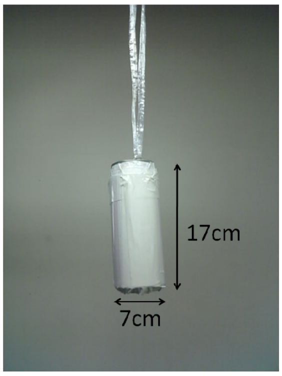

Fig. 12. The obstacle used for Action 2

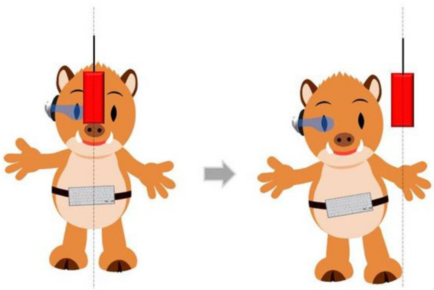

Fig. 13. Action to avoid sideways

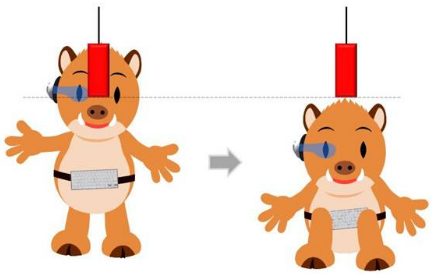

Fig. 14. Action to avoid downward

Figure 12, is used as the obstacle in this evaluation. He/she makes two actions; the first is where he/she avoids the obstacle sideways, as shown in Figure 13, and the second is where he/she avoids it downward, as shown in Figure 14. He/she makes these two actions and answers the questionnaire on the ease of avoiding the obstacle (5: it is very easy to avoid it – 1: it is very hard to avoid it).

Action 4: A subject looks for five objects located around him/her within a radius of five meters at random. Then, he/she answers the questionnaire on the ease of recognizing his/her surroundings (5: it is very easy to find the objects – 1: it is very difficult to find them).

We used the stuffed suit shown in Figure 7(a) for Actions 1, 2, and 3 and used the stuffed suit shown in Figure 7(b) for Action 4. For Actions 1, 2, and 3, subjects can see the images taken by the camera attached to the eyes of the stuffed suit in our method. For Action 4, there is another proposed method in addition to the case of Actions 1, 2, and 3: there are five cameras around the face of stuffed suit. The conventional method means that subjects acted with the view from the hole made in the stuffed suits.

Results of Action 1. Table 4 summarizes the average score for Action 1. In its ease of understanding, the proposed method earned higher scores than the conventional method. In addition, from the t-test for the score for the ease of understanding, there were significant differences (t value=-5.10, $p<0.01$) and this confirmed that performers were able to react to the action taken at the position of the eye of stuffed suits smoothly with the function of enhanced visibility. In the ease of making actions, the proposed method also earned higher scores than the conventional method while there were no significant differences (t value=-2.45, $p>0.05$). There is a possibility that subjects were not able to recognize the position of the stuffed suit's arm even when using our method.

Results of Action 2. Table 5 lists the average score for Action 2. The proposed method achieved higher scores than the conventional method. In addition, from the t-test for the scores, there were significant differences (t value=-7.48, $p<0.01$) and this confirmed that the function of enhanced visibility was useful for moving the gaze of stuffed suits accurately.

Results of Action 3. Table 6 summarizes the average score for Action 3. The proposed method earned higher scores than the conventional method in both actions while there were no significant differences from the t-test for the scores (avoiding obstacle sideways: t value=-1.04, $p>0.05$, avoiding obstacles downward: t value=-1.51, $p>0.05$). The reason for this may have been that subjects could not recognize the exact distance between the stuffed suit and the obstacle because they were watching the images from the camera when using the function of enhanced visibility. To solve this problem, we need to devise a method where performers in stuffed suits can recognize the distance between stuffed suits and objects.

Results of Action 4. Table 7 lists the results for Action 4. From the results, the proposed method with five cameras achieved the highest score. There were significant differences (f value=34.67, $p<0.01$) from one-way ANOVA. As a result of multiple comparisons between each pair of methods using Tukey's test, there were significant differences between the scores when using five cameras and when using the conventional method (t value=-8.08, $p<0.05$) while there were no significant differences between the two proposed methods (t value=-2.31, $p>0.05$). One of the reasons for this is that subjects were able to move their bodies without caring about the surroundings because there were no obstacles around the stuffed suits in this experiment.

We confirmed throughout that performers could react to actions made at the position of the eye of stuffed suits more easily and they could move the gaze of stuffed suits accurately by using the camera attached to the eyes of the stuffed suits. In addition, we also confirmed that performers could recognize surroundings more easily with multiple cameras attached to the heads of stuffed suits. Therefore, performers can communicate with others smoothly and naturally by using the function of enhanced visibility.

Table 4. Result for Action 1

	Proposed	Conventional
Ease of understanding the action	4.4	1.8
Ease of making action	3.8	2.6

Table 5. Result for Action 2

	Proposed	Conventional
Ease of moving gaze	4.4	1.6

Table 6. Result for Action 3

	Proposed	Conventional
Easiness to avoid sideways	3.4	2.2
Easiness to avoid downward	3.6	2.2

Table 7. Result for Action 4

Proposed		Conventional
Five cameras	One camera	
4.4	3.6	1.6

Conversation with the MC

Fig. 15. Performance on the stage

6 Actual Use

We used the prototype system on the stage at Illumine Kobe 2010 [15] held at the Hyogo Prefectural Museum of Art in Kobe City on December 12th, 2010. The staffed suit with our proposed system communicated with the MC and danced to music, as shown in Figure 15. It confirmed that the performer in the stuffed suit could communicate with the MC by looking at him naturally and he/she could act by himself/herself because it was easier to recognize the surroundings. However, there was a problem in that it was hard to see the camera image when the light on the stage was not bright. In the future, we need to consider the use of infrared cameras to gain visibility even in the dark places.

7 Conclusion

This paper proposed a system of supporting performers in staffed suits and implemented functions to provide support in posing and enhance visibility. The results from evaluation confirmed the effectiveness of these two functions.

However, the function to support posing cannot be used in amusement parks even though it can be used on stage or for training because an external camera is required. We have to devise a way of using our method in actual amusement parks without any outside cameras. We plan to use wearable sensors to detect the posture of performers. By using this method, performers will be able to identify the accuracy of their poses regardless of their standing positions and make poses accurately. We need to devise a method for the function of enhanced visibility to present distance information between the staffed suits and surrounding objects because it is difficult to gain a sense of distance. We plan to implement a function that informs performers in staffed suits of the proximity of objects with proximity and vibration sensors.

An example of application of the system could be applied to support users, such as astronauts, since they always need to recognize their surroundings in states in which they cannot move freely. In addition, when giant humanoid robots are created in the future, the importance of the system to enhance visibility and to extend the sense of embodiment will increase.

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