International Journal of Service and Knowledge Management
International Institute of Applied Informatics
2020, Vol. 4, No. 2, 54 - 70

Development of OSONO, a Service Robot with Reference to "Joruri puppet", and its Choreography

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Abstract

It is expected that various service robots will be widely used and utilized in commercial facilities where coexistence and affinity with humans are required, as well as business spaces such as public facilities, tourist facilities, nursing care and welfare facilities. These service robots are required to attract people and to enable to exchange messages with each other. For one of this solution, by our original methodology, we have developed a physical robot named OSONO, with referencing to the Japanese traditional puppet theater, which is registered as a World Intangible Cultural Heritage. In this paper, we propose our method to develop a robot with fine design, extract and analyze choreography of Joruri puppet, and reconstruct choreography. Particularly, we verify that this method realizes excellent choreography even a robot has a small number of actuators.

Keywords: Robot Services, Physical Properties, Choreography, Service Robot, Joruri Puppets

1 Introduction

It is expected that various service robots will be widely used and utilized in commercial facilities where coexistence and affinity with humans are required, as well as business spaces such as public facilities, tourist facilities, nursing care and welfare facilities. These service robots are required to be able to attract people and exchange messages with humans each other. For one of this solution, by our original methodology, we have developed a physical robot named OSONO (Figure 1), with referencing to the Japanese traditional Joruri (*) puppet theater, which is registered as a World Intangible Cultural Heritage. The reason that we development our original robot OSONO without using a commercially available robot is to make free without restrictions on the use of any characters. It was exhibited at the International Robot Exhibition 2019 and was well received. Joruri puppet theater is a collection of techniques that have been passed down since ancient times. In this paper, we propose our method to develop a robot with fine design, extract and analyze choreography of Joruri puppet, and reconstruct choreography. And we verify that this method

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realizes excellent choreography in one of the famous scenes even a robot has a small number of actuators.

The rest of this paper is organized as follows: In chapter 2, we describe related works and subjects. In chapter 3, we describe our method the development of OSONO, and its choreography This includes extracting/analyzing Joruri puppet's choreography, and to reconstruct choreography using minimum actuators. In chapter 4, we evaluate effectiveness of OSONO and its choreography through continuous operation at a large-scale event and a survey of questionnaires about implementation of changing the number of actuators.

*Note: Joruri puppet theater is traditional Japanese puppet show registered as a UNESCO Intangible Cultural Heritage, sometimes called as “Bunraku”. Most of Joruri puppets for Joruri Puppet theater were made in the middle of the Edo period and the Meiji era about 1700- 1900[1]

Figure 1 OSONO exhibited at International Robot Exhibition 2019, TOKYO, JAPAN

2 Related Works

In this chapter, we describe related works, such as service robots' physicality which makes people to pay attention to the robot, affordable robots and actuators and robots to act. Additionally, we set the issues of this paper.

2.1 Physical properties on Service robots

There are many researches on physical properties of service robots [2]. Particularly, there is an experiment to verify whether the robot's advice changes the user's behavior [3]. In this experiment, they evaluated whether the user's physical activity was enhanced in the following three cases: (A) Interactive counseling by a robot with physicality, (B) One-sided advice by a robot with physicality, and (C) One-sided written advice using a display. As a result, when comparing B and C, the robot with physicality (B) was superior. On the other hand, in the comparison between A (dialogue) and B (monologue), B was superior. This reason is that the illusion of pseudo-dialogue broken due to some timing shift. Furthermore, a difference of user's reaction due to a difference of the design and the shape of the robot's head is mentioned in Ref. [4][5]. There is a report of field operational tests experiment is conducted by placing robots in commercial facilities [27]. But neither of them has dealt with the gestures and the choreography of the robot in depth.

2.2 Affordable robots and actuators

In the Japanese robot market from 2017 to 2019, many service robots that are small and cheaper than $1500 have appeared on the market. These are home appliances-like designs, the minimum appearance that is easy to anthropomorphize. In addition, they can express the rich emotional expression such as adorable, kind, warm, friendly, lovable by the face display. As for voices, they can speak and recognize voices. As for the mechanism, they achieve from 2 to 8 FOD (degrees of freedom) with a relatively small number of actuators. For example, "Tapia" [6] is 2 FOD, "Xperia Hello!"[7] is 3 FOD, "unibo" [8] is 3 FOD, "Sota" [9] is 8 FOD, and "ROBOCOT" [10] is 2 FOD. Thus, in actual products, it is clear that the issue is how to minimize the number of actuators while paying attention to cost and ensuring the required quality of expression.

2.3 Robot to act

Bunraku-za was one of Joruri puppet theaters' name historically, and sometimes "Bunraku" is used as representing Joruri Puppets. In the study on robots related to Bunraku puppet, there are experiments in which puppeteers of Bunraku puppets play emotions, and collect data. Based on that experiment, researchers have designed the hardware mechanism of the robot [11] and prototyped it [12]. As a result, the designed and prototyped robot has 19 FOD and uses many actuators. Additionally, this study does not cover the design of the robot's head. As for tools, data capture is equipped with a motion capture function, which is a large-scale facility. Regarding the behavior of the target, the emotional expression is main focused [28]. So, the viewpoint of application to business is unfocused. We think that service robots are enabled to construct utilizing Joruri Puppets's high-quality behavior even robots that have fewer actuators, as we describe latter in this paper. In addition, in order to collect many good quality gestures from various analysis targets, it is necessary to reduce the burden of data collection.

On the other hand, there is an attempt that robots play drama as one of the actors [13]. However, interaction between robots and humans is realized with robots pre-programmed utterances and body movements. So, it does not cover the interaction to updated in real time, which is required in real workspaces.

2.4 Physicality and choreography of a robot

In this paper, in order to develop OSONO as an attractive service robot, there are three issues to be solved as follows:

(1) Physicality which makes people to pay attention to the robot: As good design of robot head is an important issue for attracting people, we clarify its methodology and the effect.

(2) The methodology on the robot choreography: Effective expressions of the robot choreography utilizing its physicality, such as movements and gestures, make it easier to introduce service robots into primary response service, which are reception, guidance, call out, questionnaires, and others. These will spread service robots. To realize the above, there is an issue that how the robot behaves to effectively convey the message from the robot to the audience. Particularly, for implementing it on service robots, it is necessary to systematize a series of methodologies for generating and/or extracting the choreography.

(3) A small number of actuators: It is also required that the choreography can be reconstructed on a robot with minimum few actuators. As mentioned in 2.2, in order to spread service robots, it is also necessary to achieve an attractive appearance and human interaction with a small number of actuators, in terms of cost.

In order to solve the above-mentioned issues, as for (1), we model various robot head with reference to the Joruri puppets. In this paper, we develop OSONO with reference to Joruri puppets. As for (2), we analyze the behavior of Joruri puppets on the stage and extract the characteristic points of good quality gestures. As for (3), we verify that the feature points obtained in (2) can be used to build good quality gestures with a small number of actuators.

3 OSONO with Reference to "Joruri puppet

In this chapter, we describe a development of OSONO, which is a robot with reference to "Joruri puppet". In addition, we extract Joruri puppet's choreography and analyze it. Finally, we propose a method to reconstruct "Joruri puppet" 's excellent choreography using the robot with minimum actuators.

3.1 Modeling of OSONO' head

There are two types of robots that express the physicality, which are closer to humans and abstract like the design of home appliances. The latter is discussed in a separate article [14]. However, in any case, too poor design cannot be accepted by users as a service robot. On the other hand, flexible development is possible by realizing various heads and faces of robots without bothering the designer. Therefore, the authors devise and realize a modeling method close to humans by referring to Joruri puppet (in the Joruri puppet, the head is called "Kashira". It is written as "Kashira").

In our method, as modeling process, a "Kashira" model is created using polygons whose vertices are appropriate and a relatively small number of points for representing facial features. The curved surface of the face is automatically generated by modeling software. Furthermore, by investigating the shape of the head of existing multi-class and multi-source Joruri puppet works, we confirme that the positional distribution of facial parts such as eyes, nose, and mouth is limited.

By arranging within this range, it is thought that a variety of well-balanced "heads" can be generated without copying any actual Joruri puppet design. Using this method, we modeled two contemporary different heads, referring to the work of the first Tenguhisa (1858-1943), and show that various heads were able to be created. The modeling software we used is “Metasequoia 4”. In addition, we created OSONO with a face length of 9 cm, and Joruri Robot of 5 cm using a 3D printer. OSONO has a structure that allows blinking, nodding of the neck, opening and closing of the mouth to express facial expressions [15][16]. Kashira is painted with white that contains the white fine shell powder that is used for Japanese traditional color. The reason for painting white is that the female head of a Joruri doll is usually painted white so that it stands out on a relatively dark stage. So, it is also expected to be effective at the exhibition hall.

3.2 Scene to verify

Service robots need physical expressions as messages that suit their tasks. For example, assuming the task of collecting questionnaires at an exhibition hall, the necessary behaviors are “call out”, waiting, “instruction/guidance”, “agreement (nodding)”, and “confused” (or surprised). In this case, the behaviors of a robot become an issue in order to accurately convey the intention to the visitors. In other words, we need a methodology to generate diverse and high-quality gestures and apply them to service robots. The authors show one step to solve this issue with reference to the techniques of Joruri puppet theater highly developed in Japan.

Joruri puppet theater is usually composed of the narrators, the shamisen players (music) and the puppeteers. There is "Tokohon" as a narrator's script. Tokohon usually encompass a single scene and are marked with the performance notations for the narrator and the shamisen [1]. That is, narrator-part and shamisen-part have been recorded in letters. So, it is possible to reconstruct a scene with relatively ease.

As for the choreography on puppet-part, it is said that there are about 50 typical forms of as short gestures patterns. Additionally, there are books named "Arts of Bunraku puppet" [17] and "Staging of Bunraku puppets" [18], which are transcripts of lower level movements along the stages of a typical story titles. Excluding these two books, there are few similar documents. However, unfortunately, the information on these documents are less and/or not well systematized enough to implement the choreography onto robots [19]. Therefore, in order to utilize techniques of Joruri puppet theater for service robots, it is important to systematize the choreography, such as collecting exhaustive expressions of "gestures", clarifying the relation between "gestures" and messages that you want to convey. Here are challenges.

In order to collect the good quality choreography of service robots, we investigate the operation of Japanese traditional Joruri puppet, extract the choreography and implement it on the robot “OSONO”, described in 3.1. In this section, we examined about 30 seconds at the beginning of “OSONO no KUDOKI (OSONO says)” of “SAKAYA no Dan (The scene of a Liquor store)”, which is one of the most well-known scenes of Joruri puppet theater. It is a scene where the wife waits for her husband who does not return. And, OSONO's words of this scene script is "Imagoro wa Hanshichi-san, doko de dôshite gozarôzo (And by now, Hanshichi-san, where, what are you doing?)". And OSONO's action is to lean on an andon (in Japanese, paper lantern, lamp in English), and to put her hands on it , as shown in Figure 1 [20]. In Figure 1 the Left box is an andon. From the perspective of the service robot, this choreography is expected to be used at waiting for a customer while "call out".

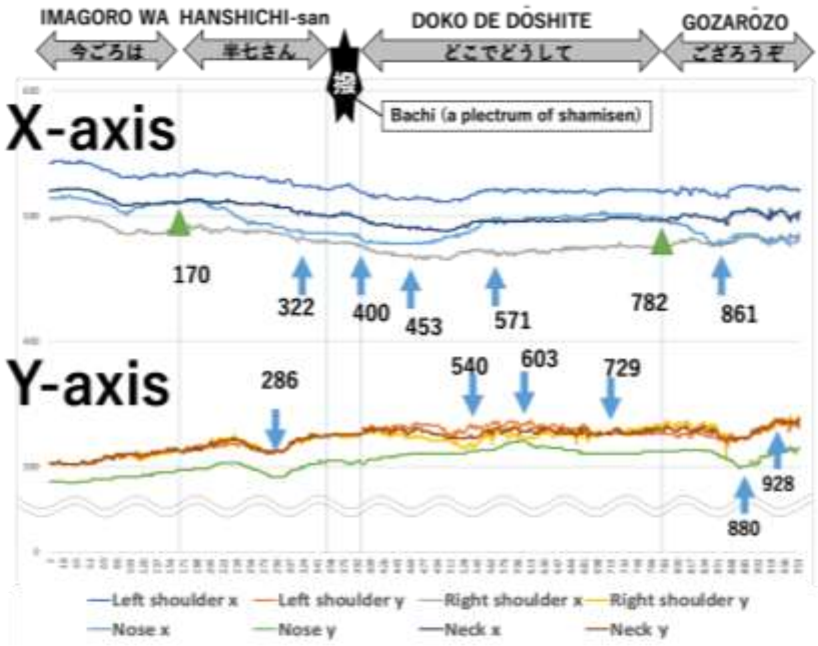

Figure 2 Locus data of the actual Joruri puppet acquired by OpenPose

3.3 Analysis of Choreography

In order to extract and analyze the puppet's choreography, we target a demonstration by Sagami Puppet Theater "Shimonaka-za", a national important intangible folk cultural property of JAPAN [21][22][23]. In analyzing the choreographies of a Joruri puppet, the locus data of each part of the puppet is extracted using OpenPose[24] that use artificial intelligence technology. The X coordinate acquired by OpenPose indicates the coordinate in the left-right direction. The larger the value, the more to the left as seen from the puppet, and the smaller the value to the right. In this choreography, because the movements of the upper body were main, the left shoulder, right shoulder, nose and neck were selected as the most characteristic parts, and the parts below the waist were omitted. Figure 2 shows these X and Y coordinates in the image frames included in acquired locus data. The horizontal axis is the time axis and the unit is the frame number acquired at 30 fps. The vertical axis represents the position change of the position of the puppet, and the unit is pixel. The purpose of this analysis is to extract temporal feature points (frames with large features) from the acquired locus data and to clarify the features. The feature points of the movement here are the angle of the head, the direction of the face (up, down, right, left) and the start of movement, stillness, and the position of both shoulders (left and right tilt, horizontal).

Also, the line breaks (horizontal arrow at the top in Figure 2) are synchronized with the start of movement, and can be feature points. Finally, 13 feature points (numbered in Figure 2) were obtained from about 30 seconds at the beginning of the 2.2 scene. We analyze main feature points below.

Figure 3 main feature points frames mapped into the simulator.
These poses are used to create the animation

･Frame 170: From where the nose and neck are vertical, start to turn the face to right with "Hanchichi-san". And, the left and right shoulders are leveled in this frame.

･Frame 286: In “Imagoro wa Hanshichi-san” of the first half, the Y value of nose is the smallest (the face is raised).

･Frame 322: The X value of nose and right shoulder is the closest in the first half. The head is horizontal and the nose is pointing to the right. Wait for a Bachi just as it is. (Bachi is a plectrum of shamisen.)

·Frame 400: Turn the face to the left with “Doco de doshite”. From this point, the X value of the face (nose) starts to change greatly.

·Frame 453: The X value of the nose is the smallest (The nose is located in the most right. It is the beginning of a series of movements) .

·Frame 540: The difference of Y value between the left and right shoulders is the largest. The shoulders are greatly inclined.

These frames will be used as the basis of the animation creation described in 3.4. Figrure 3 shows the above main feature points frames mapped into the simulator.

There are several variation of action types in this part [17][21]. They are:

(1) In Ohnishi, “Staging of Bunraku puppets”[14], the record of Yoshida Bungoro's performance writes that look over and say "Imagoro wa Hanshichi-san"(And by now, Hanshichi-san), rotate the head left and say "doko de (Where) ", And shake the head finely and say "dôshite gozarôzo (what are you doing?)".

(2) In “How to manipulate a Joruri puppet on Shimonaka-za of Sagami Puppet Theater” [21], there are different records. One is the 6th Yoshida kunigoro’s performance that pointing away with the right hand and lying down the face with loneliness. Another is Nishikawa Izaemon’s performance that is holding the hands on the edge of the andon, looking at the stage right, and speaking above lines.

In each case, the choreography is to rotate the head from the left stage to the right stage, and “look over” and “bow her head low” are added before/after rotation. This movement is quite fast. In addition, the motion is highlighted by inserting a short stop timing. This choreography type of the head rotation is called “Kurizu” (twisting the head in English). Moreover, by fine tuning the angle of the jaw and going up/down the torso, this choreography becomes more feminine gesture. Because, this type is very popular so that it not only appears four times in this story, it also appears in various other stories, including “Susi-ya no dan” (The scene of the susi shop) of “Yoshitsune Senbon Zakura” (Yoshitsune thousands cherry blossoms tree), one of masterpiece in Joruri Puppet Stories. Therefore, this type is also said to be a characteristic type for women[25].

3.4 Simulation of Choreography

Main feature points frames described in 3.3 are mapped onto the model in the simulator (Figure 3) by hand as the key frames of animation. These key frames are used to create the animation by linear interpolation toward the time axis. We used Blender 2.8 [29] as the simulator. Finally, the original choreography is re-constructed as an animation [26]. Advantages of this method is that the result animation is created with few feature points and the meaning of each feature point is clear, because it is based on the analysis results. Thus, later, you can easily correct the choreography such as additions and fine adjustments. In fact, in the example of 3.3, 13 feature points cover about 30 seconds. In addition, although in OpenPose, the noise between feature points frames of the analysis result is observed in many cases, this method is less susceptible to this noise. On the other hand, vibrations such as "shake your shoulders and cry" cannot be represented by a few feature points, so it is necessary to make appropriate supplements later.

3.5 Body, Kimono, Hair Design and Actuators

The parts that should be movable are eyes, mouth, neck (tilt forward/backward, tilt left/right, neck rotation), shoulder up/down, body rotation, body tilt (front/back, right/left), hands, and arms. However, this time, the legs are not considered.

The key of design is to be able to reconstruct the extracted choreography with a small number of actuators without excluding quality. As mentioned in 3.2, the characteristics of our target choreography is constructed the movement of the head and the hand and body leaning on the andon. Utilizing these characteristics, we design robot behaviors while verifying the movement of which part and whether the choreography can be reproduced sufficiently even if the actuator is omitted, using simulations and an actual robot.

As mentioned in 2.2, as the robot lean on the andon and their positions of both hands are fixed to the andon, the number of actuators can be reduced by passively driving the hands and arms using body rotation. In this case, the neck (tilt to the left/right, rotation of the neck) moves passively with the active rotation of the body, despite of hands fixed in position. This series of moves is realized as follows: (1) As the similar as Joruri puppeteer holds the torso skewer, OSONO's torso

Figure 4: Actuators for eyes, mouth, and neck (3 at the top) on the torso skewer and actuators for tilting/rotating the torso (2 at the bottom)

skewer is fixed to the waist (Figure 4). On the waist, actuators for body rotation and for body tilt (front/back) are equipped, (2) its torso housing is placed on the torso skewer, allowed to rotate free (Figure 5).

The andon as a prop is useful as an advertisement if this robot is used as a guide for exhibition halls, etc.

The movements of the eyes, mouth, and neck are achieved by placing three servomotors on the torso skewer (Figure 4) and pulling with a string. The hip joint can have three degrees of freedom: rotation of the torso, tilting forward and backward, and tilting of the torso. The active degree of freedom of OSONO (equal to the number of actuators) is evaluated in the range from 4 to 6. In addition, the nod of the neck and the tilt of the body to the left and right can be approximated by the tilt of the body to the front and back and the rotation of the body. Therefore, these movements can be approximated by 2 to 5 active actuators.

As for an implementation, OSONO is 39cm tall. It's active-joints were implemented by PWM servo motors. Particularly, to rotate and tilt the torso, we used servo motors with 48.0kg cm torque. One Arduino UNO board connected to the servomotor, which controls the choreography and the

Figure 5: OSONO's robot body and 3 actuators at the waist for its torso

timing, is controlled by an external PC. Passive-joints such as shoulders, arms, and wrists are structured so that they can be moved freely by connecting them with a thread based on a traditional thread puppet (Figure 5).

Clothes and robot-body are directly connected to the quality of physicality that a torso, arms, hands, and a head create together with. In addition, it needs to be easy to put on with good balance, and easy to take off. Standard Joruri puppet's body consists of a shoulder plate and a body ring, which are connected by cloth. The kimono (**) is sewn on that cloth. In OSONO’s case, the torso of the robot-body, which include its shoulder plate, resembles the human body and works as an exoskeleton that so that the kimono does not lose its shape. OSONO's kimono is similar to people's kimono, but the collar part is independent and reduce the adjustment for dressing. In addition, the body of OSONO’s kimono is attached to the torso of the robot-body, which is attached to the body skewers as we have already mentioned. For the kimono, we used a soft cloth so that the folds naturally appear, the sleeve was hung on the arm with a margin so that it could move freely with respect to the arm, and the cuff was glued to the forearm. For the color of the kimono, we used bright colors or a reddish color that is conspicuous for the exhibition. The kimono pattern was chosen to be small, so that the ratio of the pattern to the robot size was kept realistic. The vibration generated from the robot body is highly absorbed by the kimono, as a side effect. Figure 6 shows OSONO’s kimono parts that we made. The big one on the right is a kimono. The tape-shaped one on the top is the collar of the kimono that is layered under the kimono. The leftmost one is the bottom collar. It has cotton inside so that it can be adjust the shape when worn. The lower left two are belts, which are called “OBI” in Japan, and the left end is a knot of that belt, that can be attached to the belt.

On the hair design, the hair style is an effective means of expressing diversity. By preparing various hair styles and attaching them to the head, it is possible to provide a variety of models from modern times to the 1600s Edo period. For OSONO, we selected a typical hairstyle "Tsubusi

Figure 6: OSONO’s kimono parts

(Smashed) Shimada" of 1800's according to the target scene. This hair style is made by FDM (Fused Deposition Modeling) 3D printer. In spite of that one of the disadvantages of the FDM 3D printer is the stair stepping effect, the comb pattern of the hair can be clearly expressed by this effect. Therefore, it is not sanded in the manufacturing process. Moreover, un-sanded plastic shine gives a good representation of the light reflections of the hairstyle, which is fixed with oil.

On the other hand, analyzed results of the choreography is mapped to the rotation of actual robot's joints as follows:(1) Expands and contracts the rotation of each joint to a physically available range, (2) In terms of time, values between feature points are calculated by linear interpolation. Additionally, hold the rotation value of each joint processing for a certain period of time at the local maxima and maxima of each rotation. This is aimed at the effect of "taking pose" that makes the characteristic points stand out, and we call it "micro-pose", (3)When required to reduce the actuators for the evaluation described in Chapter 4, they are distributed to joints that achieve similar movements.

**Note: Kimono is traditional Japanese clothing. Until the mid-19th century, both women and men wore kimonos. Most of Joruri puppets for Joruri Puppet theater were made in the middle of the Edo period and the Meiji era about 1700- 1900. Thus, Joruri puppets wear kimonos.

4 Evaluation

In this chapter, we clarify that good robot head design and good expression of the choreography are the important elements to pay attention to the service robot. Furthermore, we evaluate the number of actuators that can create the quality of choreography expression to be implemented.

4.1 Evaluation at large events using actual robots

4.1.1 Evaluation of the head modeling

At the Japan Robot Week 2018 held at Tokyo Big Sight in October 2018, "Kashira Robo" and "Joruri Robo" (the same head modeling is used as OSONO's) were demonstrated to call out and to collect questionnaires, which is linked the questionnaire service [15][16]. As results, many visitors stopped and were looking at the robots for a while. Reactions from visitors on these robots was very good. Several people were surprised and asked us whether the robot head was purchased. In this way, the "Kashira" presented in Chapter 3 can be said to be that the robot head design is good enough in attracting visitors.

4.1.2 Evaluation of the choreography

At the International Robot Exhibition held also in Tokyo Big Sight in October 2019, OSONO, implemented the choreography, which is described in 3.2, was exhibited. As results, many foreign visitors, children, and young women stopped. The reaction to OSONO's choreography was very good, such as looking at the robot, taking a movie, reacting to the robot itself, and reacting to its choreography. That is, the effect of physicality that exerts a high effect of attracting customers could be verified.

4.2 Evaluation in the choreography view point

Questionnaires were conducted in order to evaluate the effect of the number of actuators in the choreography, and the effect of blinking eyes and opening and closing the mouth of speech. The results are shown in Tables 1, 2 and 3. In the questionnaires, four simulation videos, and three choreographies implemented on the actual robot, OSONO, were displayed and answers were obtained. In this test case, the number of actuators for the choreography was changed from 2 to 4, by switching on/off at body's tilt forward/backward, body's tilt left/right, and head nodding. Actual test case are the follows:

A. Body's tilt forward/backward, Body's tilt left/right, Head nodding, and Body's rotation (4 actuators)

B. Body's tilt forward/backward, Head nodding, and Body's rotation (3 actuators)

C. Body's tilt forward/backward, Body's rotation (2 actuators)

D. Head nodding, Body's rotation (2 actuators)

Table 1: Evaluation result by simulation

Test case	A	B	C	D
(1) No discomfort in the choreography	2.5	2.5	2.8	2.9
(2) Big choreography	2.6	2.6	2.8	2.6
(3) Choreography is clear	2.4	2.4	2.9	2.8
(4) Choreography quality	2.5	2.5	2.8	2.2
Average	2.5	2.5	2.8	2.8

A, B, C, D: see descriptions in 4.

Table 2: Evaluation result by actual robot

Test Case	B	C	D
(1) No discomfort in the choreogra-	2.8	2.9	2.7
(3) Choreography is easy to under-	2.5	2.5	2.7
(5) Attractive	2.1	2.1	2.3
Average	2.5	2.5	2.6

Test case symbols are the same as in Table 1

Table3: Evaluation result for Effects

(6) Eye blinking effective?	1.8
(7) Opening/closing the mouth effective?	2.3
(8) Fine head nodding effective	2.2
(9) Choreography	2.2

In the simulation video case, A, B, C, D were carried out. In the actual robot case, B, C and D were carried out. Blinking eyes, opening/closing of the mouth, and fine head nodding were performed only on the actual robot case. The questionnaire was conducted three times. In the first evaluation, simulation video and actual robot are used and master students in information processing technology responded. In the second evaluation, an actual robot was used and separate master students in information processing technology and professors responded. In the third evaluation, and actual robot is used and researchers on robotics responded. The total number of respondents is 32.

The question items of the questionnaire are (1) there is no discomfort in the movement? (2) the choreography is large? (3) the choreography is easy to understand? (4) the choreography is good quality? (5) whether it attracts people, (6) Blinking is effective, (7) Mouth opening and closing is effective, (8) Small nodding is effective, and (9) you can easily distinguish the choreography in test cases?

Respondents rate these on a scale of 5 (1. Very good, 2. Good, 3. Normal, 4. Not so, 5. No). The result was gained as the averaged value. Regarding (9), respondents rate in 3 levels (1. I noticed an immediate difference 2. Not so different, 3. I did not notice).

4.3 Results and Consideration

In Tables 1 and 2, many of the respondents feel that the quality of OSONO's choreography is good. On the other hand, regarding the number of actuators, in the actual robot, there is no

Figure 7: extended OSONO with 4 FOD

difference in extreme evaluation between 2 and 3 actuators. Among various selections, B (3 actuators case), in which nodding (tilt front/back of the head) and body's tilt front/back were made at the same time, was highly evaluated, and it could be said that it was easy to understand and attractively expressed. On the other hand, the evaluation does not improve remarkably for A (the number of actuators is 4), which adds body's tilt left/ right tilt. In this evaluation, we evaluated the examples of "Kurizu", the deep head swing, in well-known scenes. It will be expected that there is a possibility that good results could be achieved with relatively few actuators, even for other choreography that require more actuators.

Apart from these evaluations, we have extended OSONO to support 4 actuators for the choreography (Figure 5 and Figure 7, It is taller than the case in Figure 1). And we realized test case A, which requires Body's tilt forward/backward, Body's tilt left/right, Head nodding, and Body's rotation. Finally, we have compared this with the above evaluation by two robot researchers. As a result, despite that extend OSONO can up and down its shoulders, but it did not look too different. It can be said that this is the same result as the simulator in Table 1.

In addition, the questionnaire results (Table 3) on the effects of blinking, opening and closing of mouth, and fine nodding of the head were all favorable, and the evaluation of blinking was particularly high. Blinking is not in traditional Joruri puppet, but it can improve its appeal.

4.4 Business viewpoint consideration

Based on the knowledge of OSONO, we consider the application to service robots from the viewpoint of business.

As a result of OSONO being developed with reference to Joruri puppets, it has become possible to attract and pull in customers very well as a service robot. The reason seems to be the quality of the head design and the quality of the choreography. If we proceed with these studies in the future, we will be able to obtain more valuable results. Although there are many home appliance style service robots, but OSONO has a uniqueness on a design close to humans. This seems to have many advantages such as being easy to adapt to the application to the elderly people. In addition, we showed that a high-quality choreography was realized despite the small number of actuators. This suggests that even a low-cost robot can realize a high-quality choreography.

As the future work, in order to expand the scope of application based on this knowledge, it is necessary to research the realization of diversity of the choreography, reaction to visitors, and arms and hands, which allow to represent the choreography. It can be said that it is possible to apply some of the technologies proposed in this paper, such as the design method of the head, to business.

5 Conclusion

In order to improve the physicality of the service robot, we developed a robot with reference to Joruri puppets, extracted and analyzed choreography, and proposed and verified a method that allows robots to reconstruct high-quality choreography. At the same time, it was verified That one famous scene could be reproduced with a small number of actuators using an actual robot. In the future, we will expand and systematize the range of choreography and utilize them in robot user interfaces in cooperation with related people.

Acknowledgement

This work was supported by JSPS KAKENHI Grant Number 20K12011.

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