Design of a Robot that is Capable of High Fiving with Humans

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Abstract— **High fiving enhances communication in human society. Therefore, a robot that is capable of high fiving could build a better relationship with humans. To design such a robot, it is necessary to determine the requirements of robotic high fives. The goal of this paper is to present such requirements that were identified from the analysis of human high fives, and to show the actual implementations on a humanoid robot. The process of high fiving is composed of two phases: people determine a high five motion according to the current occasion, and then they adjust the motion according to the situation surrounding them. In this paper, we particularly report these motion adjustment functions, which were tested with human participants. Feedback and other requirements for an effective robotic high five are reported.**

I. INTRODUCTION

High fives are real-time, haptic, and physical interaction behaviors between two or more people. People high five in various situations (e.g. in exchanging greetings or playing team sports). By high fiving, people share some sort of emotional feeling with each other, which enhances the quality of their communication. Therefore, it is expected that high fives would play a positive role in communication between humans and robots; however, designing a robot that is capable of high fiving is difficult because even we humans do not know or are not aware of how we high five. A study to design such a robot will reveal the requirements on how to achieve a high five. Then, the study will provide a mechanism on how to high five as well.

The goal of this paper is to present the requirements of robotic high fives that were identified from the analysis of human high fives, and to demonstrate actual implementations in a humanoid robot. In particular, we discuss the importance of behavioral adjustment in high fiving. We found that people adjust their high five motions in many ways depending on circumstances. The process of high fiving is composed of two phases: (1) determine a high five motion according to the current occasion, (2) adjust the motion according to the surrounding situation. Based on this analysis, we identified the requirements (parameters) for implementing robotic high fives. We also conducted tests with human participants to determine whether the robot could adjust its high five motions appropriately under different circumstances. Feedback that was obtained from the participants as well as observations made during the tests are reported.

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II. RELATED WORKS

Human high fives have been mostly studied in the context of team sports. By touching each other, we obtain a sense of soothing [1] and mutual benefit [2]. We also maintain and strengthen team ties, thus enhancing team performance [3]. Other studies claim the effect of haptic interaction in building relationships, for example, increasing compliance with requests [4], [5], [6]. It is also studied that compared with other bodily contacts, people are less resistant to contacts using their hands [7]. Together with other hand-based types of contact such as handshakes and holding hands, people high five in a wide region with many cultural backgrounds. High fives are usually accompanied by positive emotions. People share some positive emotion with others by high fiving. Sharing of emotions plays an important role in building a good relationship in various cases [8], [9]. High fives can be done with or without verbal expressions; people can share some emotional feelings by even just high fiving with no utterance at all. In fact, it is known that sometimes non-verbal expressions are more effective in sharing emotions with others than verbal expressions [10]. A study claimed that emotions can be communicated through body language [11]. In the human-robot or human-agent interaction study, researchers discussed the effects of emotion and empathy in building a relationship between a human and a robot, or a human and an agent. Studies revealed that empathic emotions have positive effects on a human-agent interaction [12], and more empathy is necessary in a human-agent relationship [13]. Another research proposed a methodology for the mechanical realization of expressing an emotion and intention for nonverbal communication of human-friendly robots [14].

There are studies about the haptic interaction between a human and robot, handshake or hug [15], [16], [17], and a haptic creature [18]. Because the high five is an emotional interaction and is assumed to be a useful method to build a relationship; there are some examples of using the high five in the human-robot interaction [19], [20]. High fiving is a synchronized interaction between two persons; therefore, to effectively implement the high five motion requires a detailed study. There are some studies about human-robot synchronized interaction that uses the high five as an example [21], [22], [23]. In the case of the human-robot physical interaction, even the detailed parameters of the robot motion have influences on the impression of humans. For this reason, there are studies aimed at revealing the motion parameters preferred by humans in the case of a handshake [24] or hand over [25], [26], [27]. A research claimed that the

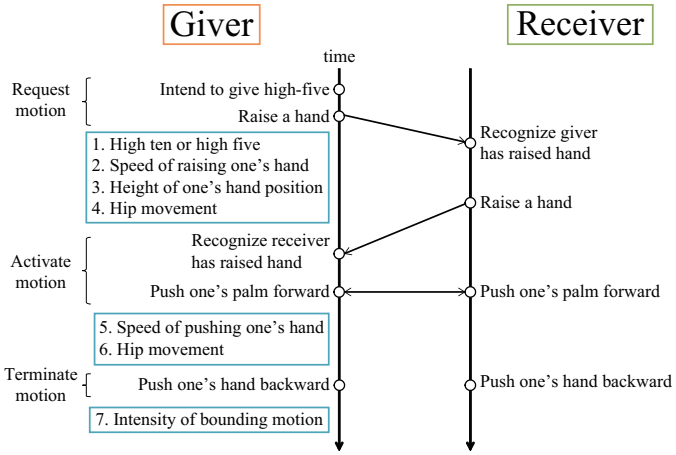


Fig. 1: High five flow

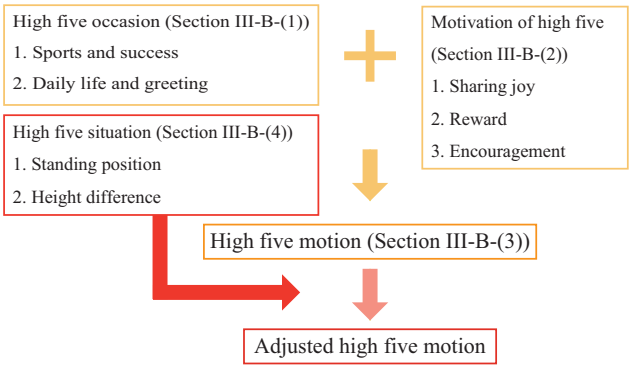


Fig. 2: High five process

robot behavior on adapting to situations has an emphatic impression to humans [28]. Another research suggested that the robot behavior adapting to the user personality and performance is more preferred by users [29]. As described, the high five is an emotional interaction, and therefore, it must adjust motions appropriately for emotional expression according to high five occasions or situations.

III. HUMAN-HUMAN HIGH FIVE ANALYSIS

In this section, we describe the human-human high five analysis. To determine the parameters of human-human high five motion, we analyzed more than 50 high five videos from social media, e.g. YouTube.

A. High five flow

In our study, we define the high five as an interaction when two people push the flat of their palm against the flat palm of the other person. Fig. 1 shows the high five flow. During the high five, there are two roles: the giver is the person who gives the high five to the other person, while the receiver is the person who responds to the giver. First, the giver has an intention to give a high five to the receiver and expresses such an intention by raising a hand to the receiver. Second, the receiver recognizes the giver's raised hand, understands the intention of giving a high five, and responds by raising a hand to the giver. Third, the giver recognizes the receiver's raised hand and pushes one's palm forward to the receiver's palm. Finally, after the two person's palms touch each other, they push their hands backward from each other. In this study, our purpose is to implement the giver's motion to a humanoid robot. With this motivation, we analyzed the giver's high five motion to determine the motion parameters. The giver's high five motion is divided into three steps: the request motion with four motion parameters, activate motion with two motion parameters, and terminate motion with one motion parameter.

B. Process of high fiving

There are many ways of high fiving. We assumed that the method of high fiving is influenced by the occasion and situation around people. In this section, we describe the relations among the occasion, situation, and high five motion. The overview of the high fiving process is shown in Fig. 2.

1) High five occasion: We tried to determine the most common high five occasion based on the analysis of high five videos, survey of literatures, and a questionnaire survey. Studies about tactile communication in sport games mentioned that sport players do high five while playing sport games [3], [30]. Another occasion of the high five is in greetings. It is said that the high five occurs in greeting occasions similar to handshakes or first bumps [31]. We conducted a questionnaire survey to determine the most common high five occasions. The participants were 12 college students (Japanese, 20-26 years old, 6 females and 6 males). The content of the questionnaire was "please write the three most imaginable high five occasions." The result revealed that the most common occasion was *sports and success* (14 votes). The second was *daily life and greeting* (4 votes). Based on these results, we decided that the most common and general high five occasions are *sports and success* and *daily life and greeting*.

2) Motivation of high five: A person who gives a high five certainly has a motivation. We classified the high five motivations into four.

- Sharing joy
  In the preceding section, we mentioned that one of the most common and general high five occasion is *sports and success*. In this occasion, it is assumed that both persons doing the high five have positive emotions. Thus, we classified that one of the high five motivations is to share joy.
- Reward
  According to a study on touch, touch enforces orbitofrontal cortex activity, which is related to emotion and reward [32]. From the high five videos, we found a high five occasion in a sports game where one player gave a high five to another teammate whose performance contributed to their team's score. Therefore, we classified that the second high five motivation is a reward.
- Encouragement
  According to a study on tactile communication, touch

can make people feel soothed [1]. From the high five videos, we found a high five occasion in a sport, where while changing players, one player gave a high five to another teammate. In this occasion, we assumed that the high five motivation is encouragement.

- Cooperation
  Kraus, et al. [3] described that tactile communication including high fiving contributes to the improvement of team performance. They mentioned that tactile communication enforces cooperation. Therefore, we assumed that another high five motivation is cooperation.

3) Relation among occasion, motivation and motion: We assumed that most of the high five motions are conceived according to the occasion and motivation. In the real world, there are countless high five occasions; therefore, to cover all of them is impossible. Hence, in this study, we focused on the two most common and general high five occasions described, which are *sports and success* and *daily life and greeting*.

- Sports and Success
  The *sports and success* occasion still includes many variations of high fives. Hence, we focused on the most exciting occasion, e.g. winning the championship. In this occasion, the motivation of the high five is sharing joy. Wallbott [33] described a partial mapping from emotional state to behavior quality. He mentioned that emotions of elation and joy relate to a person's arm movement of being stretched out in front and upwards. Another research revealed that the intention of body movements during playing of instruments is to express joy [34]. We interpreted these ideas into high five motions to express a positive emotion and determined one motion parameter set as a basic high five motion in this occasion, which is described in TABLE I. This motion parameter set is determined based on high five videos. The more the players are excited, the more intense the high five motions become.
- Daily life and Greeting
  According to the result of the questionnaire survey, the high five greeting occurs particularly between close friends who have not seen each other for a long time. Thus, we assumed that this high five motivation is to sharing joy because of the meeting and cooperation to confirm each other's mind. As in the preceding section, we determined one motion parameter set as the basic high five motion in this occasion, which is described in TABLE II. Generally, in the occasion of greeting, people raise and wave hands to attract the attention of the other person. We assumed that the high five greeting is an extended motion of the greeting gesture. In addition, considering that the high five motivation is sharing joy, the more the feeling of joy to see each other, the stronger the high five motion becomes.

4) Influence of situation on motion: We assumed the process of determining the high five motion as described below. Persons determine the basic high five motion and after that, adjust the motion. In this study, we classify the factors that compose the situations into two: standing position and height difference.

- Standing position
  Depending on the distance and the direction from one person to the other person, the giver switches hands on the request motion. If the distance is short, the giver raises the opposite hand that is far from the receiver, so as not to hit the receiver. On the other hand, if the distance is long, the giver raises the hand that is nearer to the receiver. In addition, to give a successful high five, the giver turns around while raising one's hand and changes direction so that the giver and receiver can face each other.
- Height difference
  Depending on the height difference between the two individuals, the giver changes the elevation of the raised hand so that the other person can touch his palm.

IV. Implementation of robotic high five motion

In this section, we describe how to implement the high five behavior to a humanoid robot.

A. Basic robot behavior during high five

The robot used in this study is a commercially available humanoid robot Pepper [35] by SoftBank Robotics. In implementing the high five behavior on the robot, we divided it into three steps according to the high five flow described in section III.

1) Request motion: In the request motion, the robot raises a hand to a human receiver. The robot is aware of the human presence and recognizes the direction from the robot position to the human. After these two necessary steps are met, the robot starts the request motion. In this study, for the awareness of the human presence, the robot recognizes a human face in the figure from the color camera on its head. Once the human face is recognized, the robot directs its face to the human and calculates the human face position in the figure and the robot's head yaw angle.

2) Activate motion: The activate motion is executed under the state that the robot raises a hand. In the high five flow, we assumed that after the receiver has recognized that the robot is raising its hand, the receiver approaches one's palm to the robot's palm. Considering this, we attached an ultrasonic sensor on the robot's palm to detect that the receiver's palm is approaching the robot's palm. The sensor we used was the URM3.7 V3.2 ultrasonic sensor sold by DFRobot. If the measured distance is shorter than the set threshold, the robot starts the activate motion.

3) Terminate motion: The terminate motion is executed under the state that the robot's palm and receiver's palm are touching each other. To execute the terminate motion, the robot has to recognize that the receiver's hand is touching the robot's palm. The robot we used in this study has five fingers on its hand. These fingers are connected to the same motor that controls the robot's fingers opening and closing motions. If something touches the robot's fingers, the current value of

TABLE I: The motion parameter set in the occasion of *Sports and Success*

	Motion Parameter	Attribute
Request motion	High ten or high five	High ten
	Speed of raising one's hand	Fast
	Height of one's hand position	Higher than one's head
	Hip movement	Rotate yaw
Activate motion	Speed of pushing one's hand	Fast
	Hip movement	Rotate yaw
Terminate motion	Bounding motion	Intense

TABLE II: The motion parameter set in the occasion of *Daily life and Greeting*

	Motion Parameter	Attribute
Request motion	High ten or high five	High five
	Speed of raising one's hand	Fast
	Height of one's hand position	Lower than one's head
	Hip movement	No rotation
Activate motion	Speed of pushing one's hand	Fast
	Hip movement	No rotation
Terminate motion	Bounding motion	Not intense

the motor connected to its fingers changes. From this, the robot detects that the receiver has touched the robot's palm and executes the terminate motion.

B. Adjustment of motion according to high five occasion

In implementing the high five motion on the robot, an appropriate expression of emotion is necessary. We defined the values of motion parameters as shown in TABLE I and II as the basic high five motions in each occasion. Fig. 3 and Fig. 4 show the motions of the robot in two high five occasions, *sports and success* and *daily life and greeting*. The situation condition of the basic high five motion is as follows: distance: 45 cm, direction: facing each other, height: 121 cm (the same with the robot). The value of the distance is determined by Hall's interpersonal distance [36]. The high five interaction is to touch each other's palm. The lower limit of personal space is 45 cm, which is close enough to touch each other. According to a research on robot motion design for expression of emotion that applied the laban movement analysis on the robot, the body movement provided with strong features leaves an impression of joy [37]. Based on this result, we determined the motion parameters.

In this study, the robot does not perceive a high five occasion automatically. Once the robot is given the high five occasion, the robot activates the high five motion defined in each high five occasion. Automatic occasion perception is beyond the scope of this study. Instead, there are studies about scene perception [38], [39], which can be used as reference to implement the automatic high five scene perception.

C. Adjustment according to high five situation

In this section, we describe the adjustment of the high five motion depending on the situation around the robot. In the following section, we describe how to recognize these two factors and how the robot adjusts the high five motion automatically.

1) Adjustment according to standing position: We defined the high fiving areas around the robot as described in Fig. 5, which is the standard used to change the robot's behavior. The area around the robot is divided into six parts. The parameter D is a threshold of the distance on whether the robot switches the hand to be used to give the high five. The parameter α in Fig. 5 is a threshold of the direction from the robot to the receiver. In this study, we set the value of D as 70 cm and α as 40. The robot measures its distance to the receiver's position using the depth camera on its head. As described in section IV.A, the robot detects the direction from itself to the receiver's position. By using these two values, the distance and direction, the robot assigns the high five area to the receiver's position according to the given thresholds, D and α. TABLE III shows the robot's hand switching according to the high five areas in each high five occasions.

TABLE III: Hand switching according to the high five occasions. B: Both hands, R: Right hand, L: Left hand

Occasion	1L	1R	2L	2R	3L	3R
Sports and Success	B	B	R	L	L	R
Daily life and greeting	L	R	R	L	L	R

TABLE IV: Participants' data

ID	Sex	Age	Height (cm)
A	Female	23	156
B	Male	22	178
C	Male	33	176
D	Male	6	120
E	Female	4	105
F	Male	23	173
G	Female	24	153

2) Adjustment according to height difference: Adjustment according to height difference is a function in which the robot changes the elevation of its hand position so that the receiver can touch the robot's hand. As mentioned above, the robot continues to track the receiver's face with its head to provide an eye contact. Owing to this function, the angle of the robot's head pitch is dependent on the receiver's height. To adjust the robot's hand position, the robot changes its head pitch and reflects the angle change to its shoulder pitch.

V. Observations on four test cases

To evaluate the implemented adjustment function according to occasions and situations, we conducted a high five test as operational check. Participants were asked to fill in a free description questionnaire. The total number of Japanese participants was seven. The participants' data are shown in TABLE IV. To evaluate the adjustment functions one by one, we conducted four different high five tests. The robot was programmed to stand still except when giving high five.

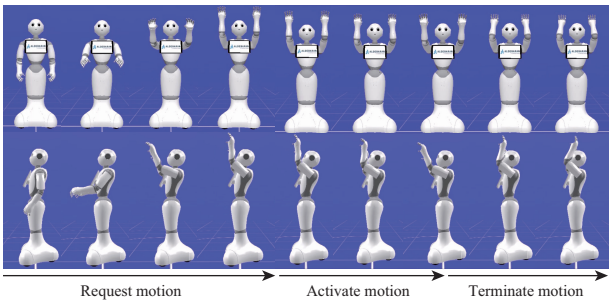


Fig. 3: High five motion in *sports and success*

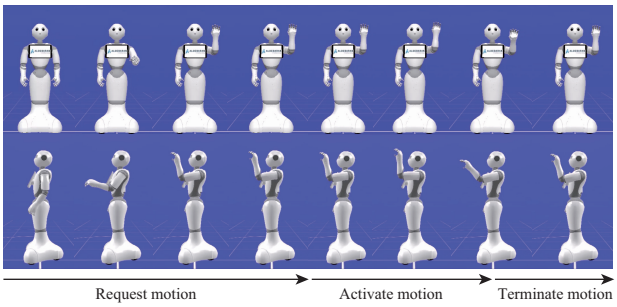


Fig. 4: High five motion in *daily life and greeting*

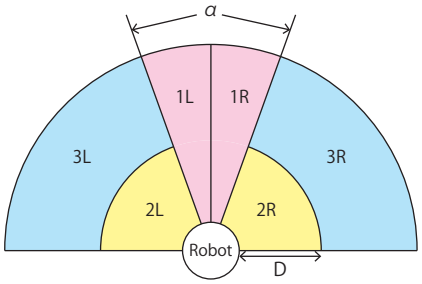


Fig. 5: High fiving areas

A. Case 1: Adjustment of motion according to the high five occasion: Sports and Success

1) Procedure: The participants were three adults, A, F and G. To evaluate if the robot high five motion we implemented matches each high five occasion, we designed high five scenarios. In the *sports and success* occasion, the participant and the robot watched a sports game video in which the Japanese team won. When the Japanese team won, the robot gave a high five to the participant (Fig. 6a). The robot gave a high five after the test performer ran the program and the robot recognized a human presence.

2) Results: In the interview after the test, the participants mentioned two main topics. One is about the motion of the robot, and the other is about the timing of touching the robot's hand.

Participant A mentioned that the robot's motion after it touched the participant's hand was natural. The intention of pushing the hand, eye contact, and bounding motion were comfortable for her. However, all participants mentioned that the robot's movement lacks the excited impression to share its emotion with the participants, especially in the request motion. Participant A mentioned that she could not recognize the intention of the high five from that motion, and it appears to be only a hand raising motion. The request motion we designed was only to raise the hand to a specified position. To improve this motion design, she mentioned that the robot should raise the hand in a little behind position, to express a holding upward motion. Participants F and G mentioned that the distance between participants and the robot test performer was set too far. Both participants mentioned as well that the request motion gave a passive impression. They mentioned that they wanted the robot to approach them in the request motion. Participant G mentioned that to share emotions with a human, the robot needs another motion before and during the high five, in addition to its hand raising motion. She mentioned that the robot's high five was done suddenly to her. Actually, before the robot gave the high five, the robot did not move at all. To share emotions in high five, she mentioned that the robot needs to express emotion with a motion before giving the high five.

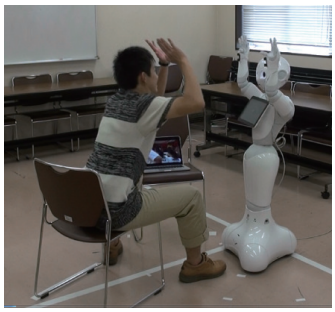
All participants mentioned that the appropriate timing to push their hands forward was unclear. The sensing ability of the ultrasonic sensor attached to the robot's palm was not so instantaneous resulting in a time delay to activate the robot's motion of pushing the hand forward. To match the timing to touch each other's palm, the participant had to wait holding up one's palm in front of the robot's palm. For this reason, participant A mentioned that the motion lacked an energetic impression. She mentioned that the robot should activate the pushing hand motion earlier.

B. Case 2: Adjustment of motion according to the high five occasion: Daily life and Greeting

1) Procedure: The participants were three adults, A, B and C. In the *daily life and greeting* occasions, the participant approached the robot from a distance and when the robot recognized the participant's presence, the robot gave a high five to the participant (Fig. 6b). Each participant was told to walk towards the robot with one's own speed. The participants were told that when the robot gives a high five to them, they should respond with a high five motion, and go past.

2) Results: Participants B and C mentioned that the timing of the robot's hand raising was appropriate and natural. In the test video, the robot raised its hand when the participant approached the robot. In addition, both participants mentioned that the height of the robot's raised hand and the intensity of pushing the hand were appropriate. Participant C mentioned that the motion of the robot was difficult to distinguish with only raising one's hand motion for the greeting. This is similar to participant A's comment described in the result of the test case 1: the participant did not recognize the high five intention from the robot's hand raising motion.

Participant A mentioned that the height of the robot's hand



(a) Test case 1: Adjustment of motion according to high five occasion: *sports and success*

(b) Test case 2: Adjustment of motion according to high five occasion *daily life and greeting*

(c) Test case 3: Adjustment of motion according to standing position

(d) Test case 4: Adjustment of motion according to height difference

Fig. 6: Four test cases

was not appropriate, and a higher position was better. In this scenario, she imagined a more exciting meeting with some friends. She mentioned that the excited emotion is related with the height of the hand position. In addition, as a reason why she preferred a higher hand position, she commented that in the human-human high five, people raise their hands higher than one's head to attract attention. She commented that the lower high five we designed in this occasion was appropriate for repeated high fives, such as those in a basketball game.

She mentioned as well that when the high five giver and receiver were approaching each other, the distance between the giver and receiver affects the timing to activate each motion, i.e., the request and activate motion as we described. There are two different distances to begin each motion, a longer one for the request motion and a shorter one for the activate motion.

C. Case 3: Adjustment of motion according to standing position

1) Procedure: The participants were four adults, A, B, F and G. Each participant was told to stand in the position which the test performer instructed. They were told that when the robot gives a high five, the participant should respond with a high five motion (Fig. 6c).

2) Results: In the test video, the fact that the robot was operated appropriately according to the participant's standing position was observed. No participants were struck by the robot's arm. In the interviews, participants A and B mentioned that the change of the robot's motion depending on the participants' position was natural and appropriate. Participant F mentioned that in the case of area 2L or 2R in Fig. 5, he did not feel unnatural. However, in the case of area 3L or 3R, he mentioned that the rotate motion was not necessary; only raising a hand to the human is enough. If the robot rotates to face to participant, he mentioned that either hand is appropriate to use. He mentioned as well that in the human-human high five, if both persons used their right hands, the body distance between both persons is more emotional than in the case when one person used the right hand and the other person used the left hand.

On the other hand, participant G mentioned that the robot motion in the case of area 3L or 3R was natural and light. She mentioned that the robot motion in the case of area 2L or 2R gave the impression of something exaggerated because of the rotary motion involved. She mentioned that owing to the rotary motion, the robot gave a polite impression.

On another topic, participant A mentioned the need for a robot's voice. All participants noticed the beginning of the robot's high five motion with the robot's motor noise and looked at the robot. Participant A mentioned that when she stood without looking at the robot, she was confused because she could not feel the desire for a high five. To inform the beginning of the high five, especially when the receiver is not looking at the giver, she mentioned that a voice signal (e.g. "Yeah!") may be necessary.

D. Case 4: Adjustment of motion according to height difference

1) Procedure: The participants were three adults and two children, A, B, C, D and E. Each participant was told to stand in front of the robot facing it. They were told that when the robot gives a high five, the participant should respond with a high five motion (Fig. 6d).

2) Results: From the test video, we confirmed that all participants touched the robot's hand easily. In the interview, all adult participants (participants A, B, C) mentioned that the height of the robot's hand position was appropriate and they did not find any difficulty in receiving the high five because of the robot's hand position. However, at the first high five with participant E, the adjustment function was delayed. We assumed that it was caused by the participant running toward the robot from a distance; hence, the adjustment function did not work in time. This result suggests that the adjustment of the robot's hand position has to consider the distance change between the robot and receiver.

VI. Discussion

Concerning the adjustment according to high five occasions, the motion design still has room for improvement.

As mentioned by participants A and C, the robot's request motion has to be improved to express the high five intention. To this end, we are searching for additional motions in the request motion. For example, after the robot raises its hand, the robot pulls its hand back once or twice to make the receiver predict the next motion, which is the activate motion. We call this motion as a preliminary motion, which will be explored in the next research. According to the comments from participants F and G, we conclude that to share emotion with a high five, other factors must to be considered in addition to the robot's joint control. For example, the giver's movement to approach the receiver may express a stronger desire to share an emotion. The motion before the high five is an important factor as well. To share an emotion with a high five, the giver and receiver need to share the motivation of the high five. To this end, the giver needs to express an emotion, e.g. joy, before giving the high five.

Based on the results of the tests, adjustments depending on situations, standing position and height difference, were operated appropriately and they did not give any unnatural impression to approximately half the participants. The other participants felt something unnatural because of the rotate motion. According to the comments from participants F and G, it is assumed that the distance between the giver and receiver and the body direction have influence on the impression of emotion and politeness. High fives at a short distance may give an emotional impression, while the rotate motion to face each other may give a polite impression. We considered that this result could be discussed from the perspective of body torque, which means different or diverging orientations of the body segments above and below two major points of articulation, the waist and the neck [40]. It is claimed as well that the orientation of the lower part of the body indicates a "dominant involvement"; on the other hand, the orientation of upper parts like the shoulders and face indicates a "subordinate involvement" [41]. A research group suggested that a robot's body rotation has an influence on human position [42]. They claimed that "to reconfigure the F-formation [43] arrangement, it is more effective to rotate the whole body of the robot than only its head." In the case of the high five, it is assumed that high fiving while turning the whole body gives the impression of politeness and depth; in contrast, high fiving with turning only the head and shoulder gives the impression of lightness and/or shallowness of emotion.

On the other hand, the adjustment according to height difference has room for improvement. In this function, we designed the robot's hand position to be synchronized with its head pitch. Thus, the robot only tracked the receiver's face, without foreseeing that the receiver is approaching the robot. As described in Hall's interpersonal space, the distance between the giver and receiver when they touch each other does not vary so much, even though we consider individual differences. In addition, the human height can be estimated by using the color and depth cameras. Hence, the robot may be able to predict the appropriate hand elevation based on the estimated receiver's height and expected interaction distance. This may solve the time lag of adjustment.

Overall, the time lag of touching each other's palm had a negative impression on the high five. To share an emotion through a high five, a successful experience of the high five is crucial. In other words, the matching of the timing to touch each other's palm is necessary. In the tests we conducted, the robot's motion was confusing for participants to estimate the appropriate timing to push their hand. To solve this problem, the robot should recognize the timing when the receiver raises one's hand. As mentioned by participant A, there should be a standard distance to activate the request motion and activate motion. If the robot activates each motion by recognizing the raising of the receiver's hand at a standard distance like feed forward control, the time lag problem may be solved to a certain extent.

VII. Conclusions

In this paper, we presented the requirements of robotic high fives that were identified from the analysis of human high fives, and showed actual implementations on a humanoid robot. In the implementation, we focused on the importance of behavioral regulation in high fiving. We proposed a process of determining the high five motion. Based on the process, we implemented adjustment functions depending on high five occasions and situations around the robot. As an adjustment function according to the high five occasion, we determined two motion parameter sets in two major high five occasions. As an adjustment function depending on the situation around the robot, we implemented an automatic adjustment of motion according to standing position or height difference.

To observe whether the robot could regulate its high five motions appropriately with these adjustment functions, we conducted four tests with seven human participants. As a result, the adjustment function that depends on situations was demonstrated appropriately. However, the robot's high five motion that we designed in two major high five occasions still had room for improvement. We found that to share an emotion with a human by high fiving, other important factors have to be considered, for example, the approaching movement, influence of distance and body torque, and expression of emotion before the high five. In addition, to share an emotion through a high five, a successful experience of the high five is important. It is assumed that the time lag to touch each other's palm caused a negative impression of the high five in totality. To implement a successful high five interaction between a human and robot, we have to explore many possibilities that were found; for example, the relation between the distance and timing to activate the motion, or voice effect prior to or during the high five.

Acknowledgments

This work was supported by JSPS KAKENHI Grant Number 15H01708.

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