REACTION FEEDBACK AS A LIFELIKE IDLE INTERACTION OF HUMAN-ROBOT INTERACTION

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Abstract: The way of emotional interaction between human and a product can be how we see, hear, and feel about it. In case of computer, as an advanced product, the upgraded interaction through eyes, ears, and fingers made emotional communication between human and product possible. On the other hand, recently as interests in intelligent robot are increasing, there have been many studies about various kinds of communication method to enhance the intimacy between humans and robots. For better and effective interactions, we can apply the way of human-human interaction to human-robot interaction. In human-human interactions, not only verbal expression but also combinations of both verbal and non-verbal expressions make smoother communication. Likewise, in human-robot interactions, there should be combinations of modalities appropriate to the situation. As the expectancy derived from the appearance of the robot becomes higher, it is necessary to develop more effective ways of continuous natural interactions. Therefore, this paper presents the possibilities of anthropomorphism in human-robot interactions through the concept of idle interactions. For the first approach, this paper is contending a research about robot feedback, which shows that the robot is in progress after an input from human. We applied the concept 'progress bar' generally used in HCI to the robot to find out the most efficient reaction feedback for human-robot interactions. Through an experiment design based on the concept of idle interactions, a usability evaluation with an applied form of reaction feedback was gathered from 36 subjects. On the basis of the results, a framework of an experiment design in human-robot interactions was built and an application to an existing humanoid robot was made.

Key words: Human-robot interaction, Socially interactive robot, Idle interaction, Lifelike behavior, Reaction feedback

1. INTRODUCTION

As the interests in socially interactive robots are increasing throughout many fields of research, there have been various types of studies made regarding communication methods to enhance the intimacy between humans and robots. If the studies on human and computers were the mainstream issue of the personal computer age, studies of different types of human-robot interactions are now required to prepare for the upcoming personal robot age.

Humans are experts in social interaction. Thus, if technology adheres to human social expectations, people will find the interaction enjoyable, feeling empowered and competent [1]. The underlying assumption for socially interactive robots is that humans prefer to interact with machines in the same way that they interact with people [2,3]. There is a growing trend toward creating more natural and user-friendly user interfaces in various fields, and this holds for robotic applications as well. The development of robotic systems enabled with interaction capabilities more similar to human-human interactions has become a hot research topic [4,5,6,7,8]. This has been a serious issue in the development of an emotional robot, which can be summarized by anthropomorphism in human-robot interactions.

As shown in Fig. 1, there are two principal aspects in the designing of socially interactive robots that are intended to interact with human socially via communication. The first aspect is focused on human-oriented perception. This concerns how the perceptual abilities of robots are similar to those of human beings when robots perceive human interactions. A socially interactive robot must proficiently perceive and interpret human activity and behavior. This includes the ability to track human features (faces, bodies, and hands), with the capability of interpreting human speech, and the capacity to recognize facial expressions, gestures, and other human activity. The second aspect is focused on human social expectations. It is concerned with the extent to which robots satisfy the social expectations of human beings when humans perceive a robot's interactions. To achieve natural human-robot interactions, robot must establish appropriate social expectations [1,2]. This study begins with the second aspect in the designing of socially interactive robots, focusing on how a robot can satisfy a human's social expectations.

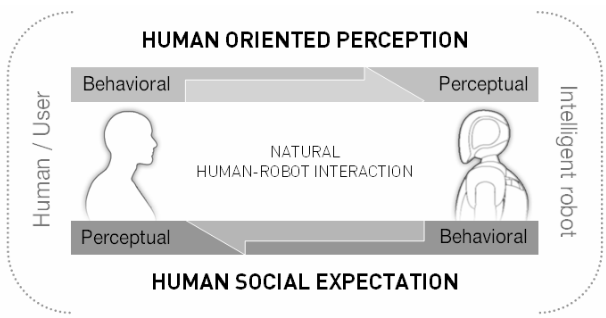

Figure 1: The two aspects of designing socially interactive robots

For natural anthropomorphism in human-robot interactions, the important criterion is to seek a balance between expectations of people and the capabilities of the machine [8]. The psychological interaction expectations, followed by the appearance of the robot, are important factors in human-robot interactions. At the same time, however, the current technology level is not sufficient to meet the interaction expectancy derived from the appearance of the robot that is similar to that of a human. To supplement the emotional interaction level between a human and a robot, this study focuses on the anthropomorphism of human-robot interactions corresponding to a human's conceptual model. In particular, this paper addresses the research concerning robot feedback, which shows that robots can receive input from humans and internally process it.

2. IDLE INTERACTION

An interface that a user naturally accepts by associating his/her experiences is called UCM (User Conceptual Model). The Mac Power Book is a fine example of this. It creates empirical reality by associating the heartbeat or respiration of a living creature [9,10]. In human-robot interactions, intuitive and emotional interactions can be achieved when the user conceptual model of the human behavior and the interaction is satisfied [11]. For example, by nodding or changing facial expressions during or after a speaker's utterance, humans convey their state of mind to the speaker and realize the conversable environment [12].
Although the challenge of building autonomous robots that interact with people may share some issues with the design of computer interfaces, robots and computers are profoundly different technologies in important ways [13]. Unlike human-computer interactions, human-robot interactions have nearly innumerable possibilities in terms of multimodal interaction modalities, sensing through eyes by appearance, movement, or light, or by other means such as through ears by direct voice communication, sound effects, or through the fingers by tangible interaction media. The listed modalities are implied not only by one sense, but also by different senses in combination simultaneously. Thus, there is a multi-sensory approach, which can improve the efficiency of interactions [14].

In addition, human-robot interactions and human-computer interactions differ in terms of the range of interaction. In human-computer interactions, a person must go to their computer (or look at their PDA or open their cell phone, etc.) in order to interact with it. In other words, there are times when people choose to interact with the computer, or not to interact with it. In contrast, people and robots as well must always deal with the physical world and incorporate idle interaction that show their existence of 'life'. Therefore, human-computer interactions can be called short-term interactions, while human-robot interactions are long-term interactions, in contrast (Fig. 2) [13]. In consequence, human-robot interactions need basic and vital interaction that shows the existence of life, whether a specific interaction with a human takes place or not. In this study, such interactions are defined as 'idle interactions'.

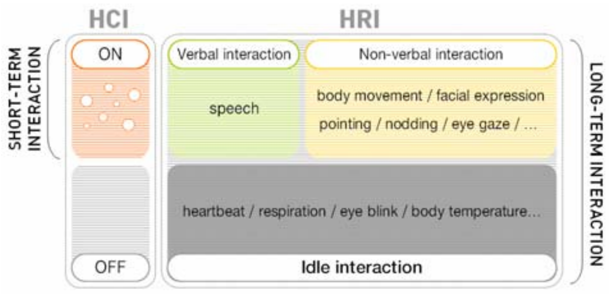

Figure 2: Difference between HCI & HRI and the position of idle interaction

The following list shows the feasible forms of idle interactions for human-robot interactions.

Heartbeat / Respiration / Eye blink / Body temperature

These are examples of "lifelike" activities which can be easily observed in natural life. To achieve the anthropomorphism of HRI, nature is the best model for lifelike activities [2]. Moreover, lifelike behavior is essential for robots that are to engage in natural communication [3]. In order for a robot to be understandable by humans, it must have a naturalistic embodiment, it must interact with its environment in the same way living creatures do, and it must perceive the same things that humans find to be salient and relevant [15].

The possible forms of idle interactions previously stated can be used to express specific intentions as well as only showing the existence of life, as a basic interaction. For the first step of the application of idle interactions to human-robot interactions, an experiment was designed that focused on 'Reaction Feedback' [1] using the form of an eye blink, which is a type of idle interaction.

3. REACTION FEEDBACK

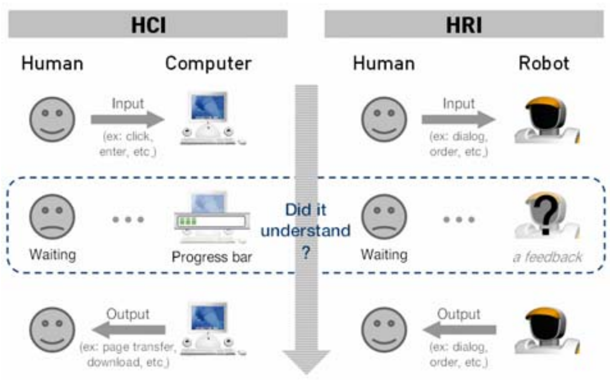

Figure 3: Reaction feedback in HCI & HRI

[1] the initial feedback that shows whether the information flow within the system progresses toward allowing the time delay

3.1. REACTION FEEDBACK IN HCI

In HCI, one of the most popular usability inspection techniques is the heuristic evaluation. This method consists of a series of ten heuristics that are used for designing usable user interfaces. Among the ten heuristics, there is a heuristic directly related to reaction feedback known as the 'Visibility of system status'. This heuristic implies the characteristic of always keeping the user informed about what is going on in the system [16]. In the results thus far achieved from various types of research on human-computer interactions, a 'progress bar' is commonly used in general personal computer interfaces taking various forms. Nielsen recommends providing a progress indicator in the form of 'percent-done' whenever the response time is expected to exceed ten seconds. According to his study, this enables the user to estimate how long a function will take, and to turn to other activities [17]. The present study also supports the efficiency of progress indicator as feedback.

3.2. REACTION FEEDBACK IN HRI

Although the present robotic technology level has numerous limitations, there have been many studies concerning HRI interfaces for natural human-robot interactions. As the research results have been applied to further practical applications and to a number of intelligent entertainment robots, a usability test for each specific system is needed. However, studies of various types of interfaces for natural interactions are at an early stage, and a well-systemized structure of modalities is required at the outset of the research. In consequence, based on the multimodality of human-robot interactions, a detail process of robot feedback is defined for this study. Accordingly, a systematic structure of robot feedback considering the feedback modalities of HCI and human-human interactions in addition to a consideration of the modalities of existing intelligent robots was created.

4. STRUCTURE OF REACTION FEEDBACK

To have a human wait and allow a time delay after an input, showing that the robot is ready to receive input is important at the previous stage. Therefore, an appropriate reaction feedback is important. Fig. 4 describes the interaction process with time, assuming that the robot is ready to receive an input.

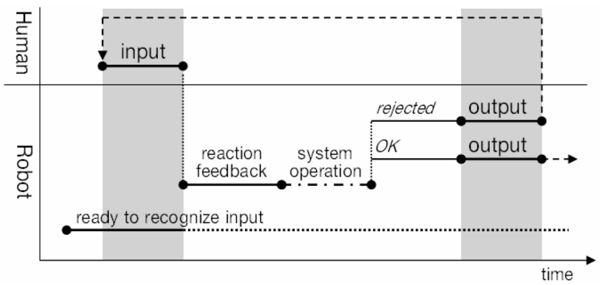

Figure 4: Interaction process including reaction feedback

The interaction process in detail is as follows: First, when a robot receives a specific form of input, it provides appropriate reaction feedback in order to have a human wait through the time delay. Next, when system operation is successful, a suitable output results. If it fails or if a suitable output does not exist, the robot provides an output that shows the rejection of interaction, with the intention of encouraging the human to make another input using a different method.

The situation and the development direction of the interaction process can affect the appropriate form of the reaction feedback. For the application of an appropriate form of reaction feedback in specific situations, a systematic structure of robot feedback was created by listing the feedback modalities of HCI and human-human interactions, in addition to the modalities of existing intelligent robots. As a result, the possible modalities of reaction feedback by the manifested characteristics can be classified into body movements, facial features, voice and sound (Fig. 5).

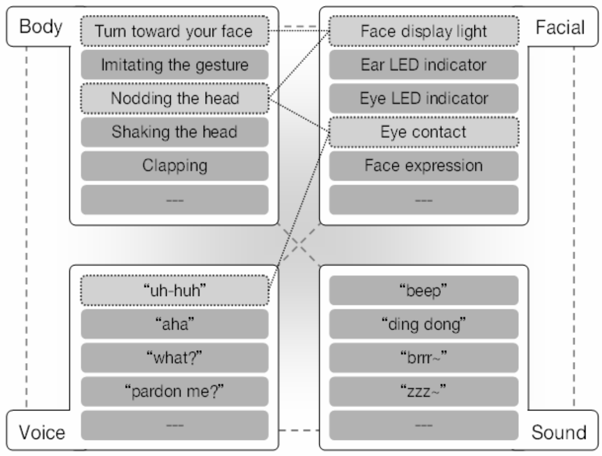

Figure 5: Structuralizing the possible forms of reaction feedback, and an example of an appropriate reaction feedback set

In human interactions, not only verbal expression but combinations of both verbal and non-verbal expressions realize smoother communication and attract each participant to the conversation, which builds the appropriate relationship among the participants [12,18]. Likewise, in human-robot interactions, combinations of various types of interactions are required for an effective 'progress bar'. The combination of five types of interactions shown in Fig. 5 is an example of an appropriate reaction feedback set extracted by considering the conditions of interaction. Such combinations can be applied in the same manner to show that the robot is ready to accept an input, and can be used as well in reaction feedback.

5. EXPERIMENT OF APPLYING REACTION FEEDBACK

A systemized approach on robot feedback is required to apply this type of interface to socially interactive robots. Therefore, based on previous works, the interaction form of 'eye blink' is suggested, which is a type of idle interaction, as an effective 'progress bar' for the robot.

5.1. METHOD

In the experiment, a form of reaction feedback was applied to a 2D software robot (Fig. 6) in a computer monitor, in order to create a usability test for natural human-robot interactions. For the experiment, the interaction form of 'eye blink' was applied as a type of nonverbal interaction as well as a type of idle interaction. This action belongs to the 'facial feature' group, from the four classes of possible modalities stated above. It is a form of interaction which can be sensed through eyes easily and intuitively.

A total of 36 individuals consisting of university students (11), master students (22) and officers (3) participated as subjects in the experiment (22 men, 14 women). Each subject interacted with all of the three types of robots (A, B, C), and the order was randomized to prevent sequential effects. Six sets of experiments (A-B-C, A-C-B, B-A-C, B-C-A, C-A-B, C-B-A) six times was held for each of 36 subjects.

In the experiment, different intervals of eye blinks (0.5 second) were applied (0.5s, 1.0s, 1.5s) to the three types of robots (A, B, C) and the experiments were evaluated by measuring the task performances and preferences of the subjects. The task was set as follows: First, the robot received a question 'How's the weather tomorrow?' as input from a human, and then a prescribed response time passed. Next, the robot answers 'Tomorrow's weather will be cloudy then clear.' as an output from the robot. The subject seated in front of the computer and makes an input with the question by simply pressing a button. The subject observed the robot until the answer came, and repeated the question according to the degree of impatience they felt that resulted from waiting (Fig. 6).

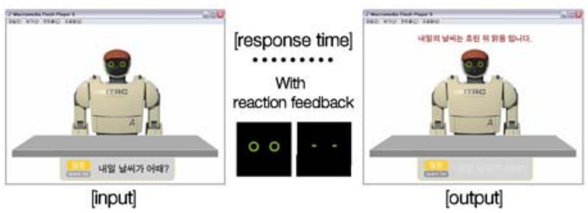

Figure 6: Experiment process and appearance of the 2D software robot

A subject's number of meaningless repeated questions during the prescribed response time, in other words the time delay from the initial input until the output, is defined as the 'Null input frequency'. This was used as a measure of task performance by regarding task performance as low if the null input frequency is high (Fig. 7). After interacting with three robots, subjects answered five-point Likert scale questions (1: very hard to wait ~ 5: very easy to wait) that measured their preferences. Lastly, the reasons behind the evaluation were investigated by interview.

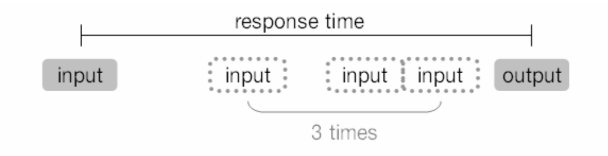

Figure 7: Null input frequency

The tool used in the experiment was created with Macromedia Flash MX, a 2D graphic software package. By holding a pilot test, the response time was set as 12 seconds, which was estimated as an appropriate time to obtain a certain number of null input frequencies. The technique for inputting was changed from a mouse click to the use of the space bar, considering the immediacy.

5.2. RESULTS

In the results of the analysis of task performance, the sum of the null input frequency was compared to the different eye blink intervals, as the null input frequency was critically influenced by the subject's personality. According to the results, the sum of the null input frequency was highest when the eye blink interval was 0.5 second (77 times) followed by 1.0 second (69 times). When the eye blink interval was 1.0 second, the sum of null input frequency was lowest (59 times), which suggests that the subjects felt it was easiest to wait for this length of time from among the three intervals.

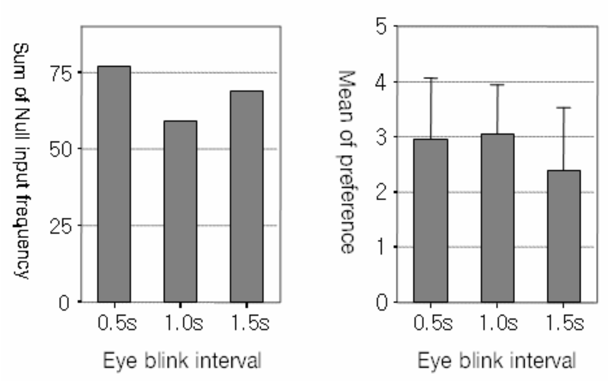

Figure 8: The sum up of null input frequency by eye blink interval (left) / the mean of the five-point scale preference by eye blink interval (right)

As a result of a within-subject design analysis of variance (One-Way ANOVA), there was a significant difference in the preference points ($F=4.145$, $p<0.05$). The mean of the five-point scale preference was the highest when the eye blink interval was 1.0 second by 3.06 (standard deviation: 0.839). When eye interval was 0.5 second, the mean of the five-point scale preference was 2.94 (standard deviation: 1.120), and 2.39 (standard deviation: 1.128) when 1.5 second, which was the lowest point of preference. Using Dunnett's T3 for post hoc multiple comparisons, the five-point scale preference difference (1.0 second eye blink higher by 0.667) for the 1.0 second eye blink interval (M=3.06) and 1.5 second eye blink interval (M=2.39) was also significant ($p<0.05$).

Although the response time of the three robots were identical at 12 seconds, after the experiment subjects said that each robot's response time felt different. The difference in psychological time observed in the experiment also can be seen as a measure of task performance as well as null input frequency.

From the analysis of statistical results and interviews, two different directions of preferences could be seen.

The first direction was that the 0.5 second interval was exceedingly fast, which made a subject's mind hurry and expect a quick answer. On the other hand, a 1.5 second interval made the subject wait without difficulty by assuming that, from the beginning, the robot operates slowly and is not 'smart' enough to give a quick answer.

The second direction of preference was that while the 0.5 second interval seemed to be exceedingly fast, making the subject wait without difficulty, the 1.5 second interval made the subject anxious due to the longer duration.

However, two different directions of preference were both satisfied with the 1.0 second interval in general. One of the reasons was that it satisfied their mental model of the nodding interval in human interactions.

From the result, various design guidelines for designing the interactions of socially interactive robots could be determined. Henceforth, the appropriate interval of reaction feedback that fits the interaction level of the robot should be applied, and the mental model of reaction feedback that human has in mind should be thoroughly considered. In addition, it was determined that the human's lifelike interactions such as eye blinks or nodding can help the considering of a human's mental model of human-robot interactions.

6. APPLICATION

Based on the appropriate interval of eye blink from the result of the experiment and the possible forms of idle interaction stated earlier, an application was made to an existing humanoid robot.

6.1. HUMANOID ROBOT "HUBO"

HUBO (KHR-3), shown in Fig. 9 is a humanoid robot developed in the HUBO Lab in the department of mechanical engineering at KAIST in Korea. It can walk across the floor with a human-like appearance and movements. It was created with the purpose of having many human-like features, movements in addition to a human-friendly character. Its height and weight are 125cm and 55Kg. It has 12 DOF in its legs and 8 DOF in its arms, with 2 DOF for each eye – a camera pan and tilt. It has 1 DOF for its torso yaw, and 7 DOF for each hand – 2 DOF for the wrist and 1 DOF for each finger (for a total of 41 DOF) [19].

Figure 9: Humanoid Robot HUBO (KHR-3)

6.2. FACIAL LED INTERFACE

As shown in Fig. 10, the facial LED interface for HUBO was designed in cooperation with the HUBO Lab. The facial LED interface consists of 18 LED lights in two rows (total of 36 LEDs). It is designed for the purpose of showing the status of HUBO. Initially, the movement of the mouth for verbal communication and idle interactions was designed to show the existence of life with the form of respiration. The movement of the mouth was designed in three levels of width matched by the voice volume of each syllables. The state of respiration was designed with LED brightness changes with movements of widening and narrowing with regular intervals. Applying the result of the experiment, the interval was set as 1.0 second in order to show intuitively that the robot has 'life'. When human-robot interactions take place, it can also function as a reaction feedback to have humans allow the time delay after a certain input.

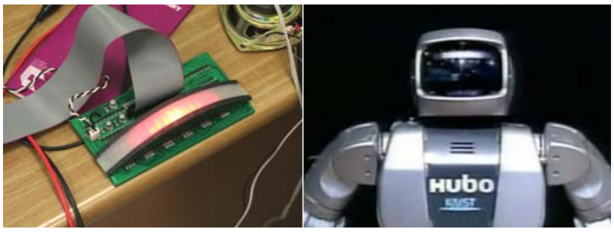

Figure 10: Facial LED interface of HUBO

7. CONCLUSION

This paper presented the possibilities of anthropomorphism in human-robot interactions through the concept of idle interactions. Through an experiment design based on the concept of idle interactions, a usability evaluation with an applied form of reaction feedback was gathered from 36 subjects. On the basis of the results, a framework of an experiment design in human-robot interactions was built and an application to an existing humanoid robot was made.

As the expectancy derived from the appearance of the robot becomes higher, it is necessary to develop more effective ways of continuous natural interactions. In addition, in order to create natural interactions, the robot design discipline should particularly consider human-friendly technology. Therefore, future work should include making structures of idle interaction with the aim of creating an application guideline, and verifying the effectiveness to natural human-robot interactions by making interaction applications using humanoid robots.

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