A survey of the effects of non-emotional motion features on emotion

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Abstract: We aim to express robots' emotions with more natural movements. In this paper, we investigate the impression of the physical characteristics of the robots' motion on the user. We found that some physical features were deeply related to emotions. First, subjects estimated the emotion close to anger when the robot's arm moved faster. Furthermore, they estimated the emotion close to anger when the robot's gestures became larger. Finally, the subjects estimated the emotion close to pleasant when the robot took longer to change its behavior.
Keywords: *Communication Robots, Human-Robot Interaction, Emotion Estimation, Non-Verbal Communication*

1. INTRODUCTION

Recently, home appliances and robots with artificial intelligence have become widespread in ordinary households. Among them, humanoid and animal-shaped robots to entertain people through communication are called communication robots. These robots communicate with humans by expressing emotions with gestures or their voices. For smooth communication with humans, robots must understand human sensibility and emotions. Also, they have sensitivities, and behave like humans or creatures.

Previous research proposed robotic emotion generation models that use psychology-based emotion models to achieve more emotional representations of living things [1] [2] [3]. Previous research proposed emotion models that can generate more complex emotions. That model uses the Self-Organizing Map to express the developmental process of emotions. Furthermore, Nakamura proposed a real-time response model that generates actions based on the emotions generated by the robot emotion generator. Robots can now express complex emotions at natural timing for various inputs by the user.

In previous research, however, the robot expresses its emotion with exaggerated gestures. When the robot and its user communicate for a long time, the user, therefore, becomes tired of the robot's behavior.

In this research, we propose an emotion expression method that indirectly expresses emotions by changing the physical characteristics of the robot's behavior that is not emotional expression. In human-to-human communication, emotions are often conveyed by attitudes and moods rather than direct emotional expressions. We, therefore, investigate the relationship between the physical characteristics of the robot's behavior and the impression it gives. This relationship could make the robot's emotional expression, more natural and easier to understand.

2. ROBOT MODEL FEATURES

2.1 Robot model outline

This research assumes that the robot and the user interact face-to-face. In this paper, we created a robot in virtual space and displayed it on the screen to simulate a situation where the user and the robot are facing each other. Fig. 1 shows an overview of the robot in the virtual space used in this research. The model presented to the user must have a familiar shape such as humans or animals when investigating the relationship between the physical characteristics of the robots' behavior and the emotions estimated by the user. This model, therefore, mimics the upper body of a human. This shape gives the user some predictability of the behavior of this model.

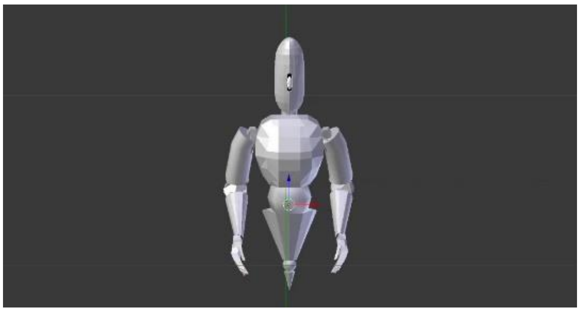

Figure 1: Robot model outline

2.2
Features of robot behavior

In this paper, we clarify the relationship between the physical characteristics of the robots' behavior and the robots' emotions estimated by the user. We made the robots' behavior greeting, as shown in Fig. 2. By changing its physical characteristics little by little, we created 20 greeting actions with slightly different characteristics.

To analyze and evaluate the experimental results, the robots' behavior must be quantitatively expressed. In this study, we numerically expressed the physical characteristics of the robot's behavior by referring to Laban's theory to numerically describe each motion [4].

Fig. 3 shows a concrete numerical representation method. First, we numerically expressed the size of the space used by the robot's behavior as Total Area. For example, when the robot does not move at all, the Total Area is 0, and when the robot stretches its arm right besides, Total Area is 1. Next, we expressed the time required for the robot to move as Required Time. Also, in the whole of the behavior, we focused on the part that expresses the purpose of the behavior. In greeting, we focused on the robot's right hand and expressed its characteristics as Hand Speed and Hand Width. Hand Speed and Hand Width, however, are set relatively in all the robot's behaviors.

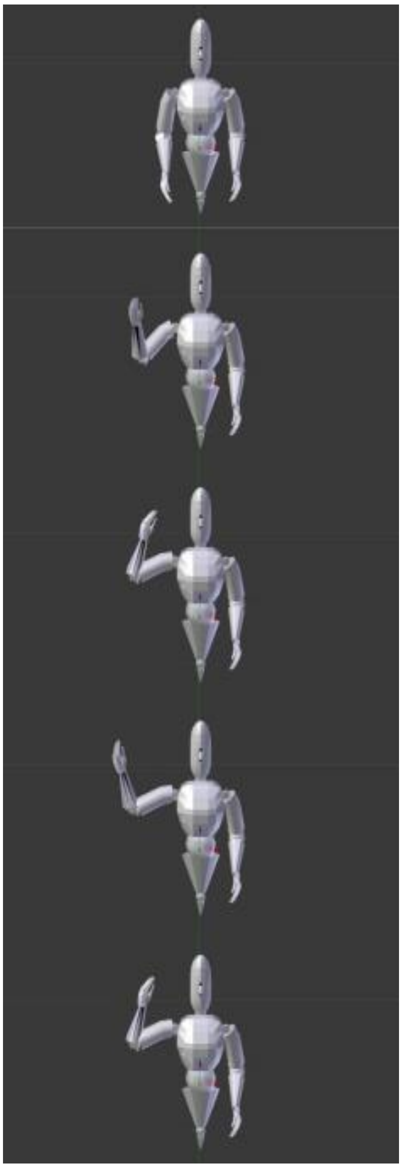

Figure 2: Robot model outline

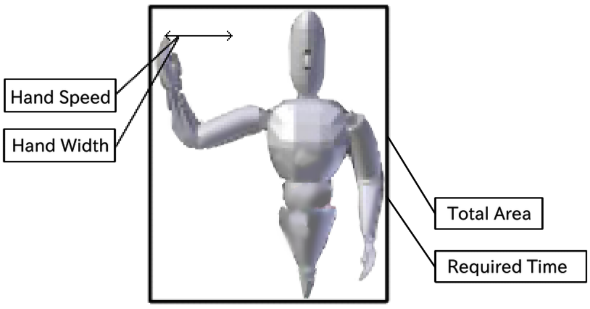

Figure 3: Robot model outline

3. EXPERIMENTS

3.1 Experiment outline

We showed the subjects the robot's behavior, as discussed in the previous section. The subjects estimate the robot's emotions for each behavior. At that time, we did not tell the subject what features of each behavior were different.

Fig. 4 shows the interface for evaluating the robot's emotions of each motion of the robot. The figure that can see in the background of the robot is Russell's circumplex model [5]. In this figure, the inside is a weak emotion and the outside a strong emotion. Also, we can represent all human emotions by using the vector on this model.

The subject evaluates the emotion by placing the robot in the position of the corresponding place on the circumplex model by mouse operation. When the subjects click the OK button at the bottom right, a new behavior is created in the center of the circumplex, and the subject evaluates the new action. At this time, the subject can see and rearrange the data that she/he previously placed. The subject repeats this evaluation. The experiment ends when all the robot's 20 behaviors are placed on the circumplex. Fig. 5–7 shows examples of the screen at the end of the experiment. In this experiment, we recode the coordinates of the robot's 20 behaviors.

Figure 4: The interface of experiment

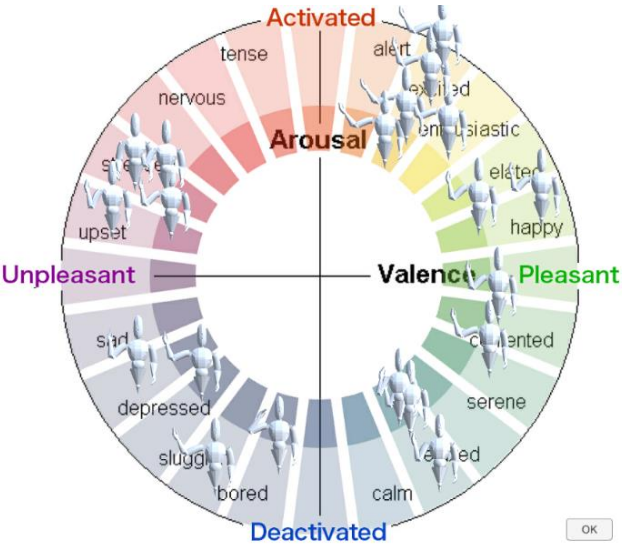

Figure 5: The example of Answer (a)

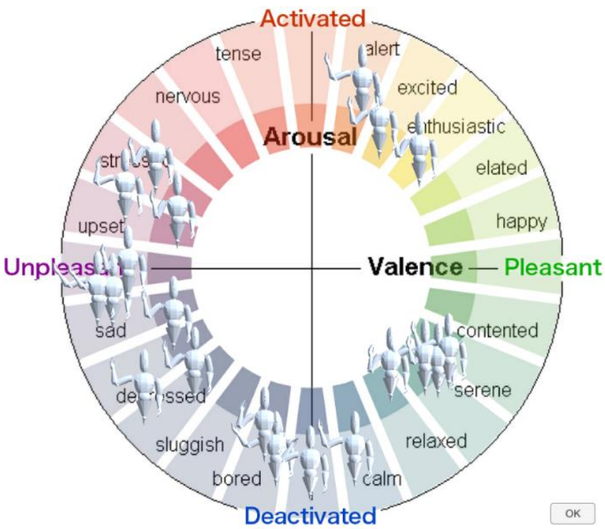

Figure 6: The example of Answer (b)

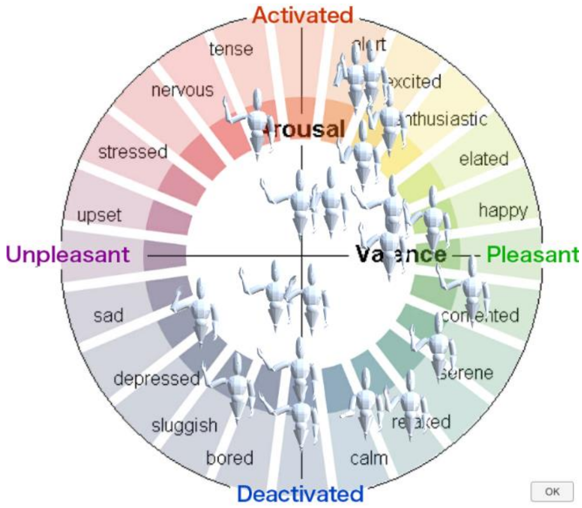

Figure 7: The example of Answer (c)

3.2 Results and Discussion

In this experiment, we showed 20 movements created in Chapter 2 to 18 subjects. We calculated the average of the subjects' evaluation of each action, and analyzed the results based on the physical properties assigned to the action. Among them, some of the physical features influenced the users' evaluation. In this paper, we express the coordinates of emotions by using a polar coordinate system that starts with the axis of pleasant emotions.

First, Fig. 8 shows the relationship between the Hand Speed and the estimated emotion. From the graph, it can be confirmed that the estimated emotion changes from the deactivated emotion to the activated emotion through the pleasant emotion so that it is almost proportional to Hand Speed regardless of the Total Area Furthermore, there is a difference in the estimated emotions even at the same Hand Speed, so other features could affect emotion estimation. We believe one of those features are Total Area. We, however, believe that this feature should be determined after additional experiments. Fig. 9 shows the relationship between the Required Time and the estimated emotion. From Fig. 9, as the time taken for the movement increases, the estimated emotion tends to change from the activate emotion to the deactivate emotion. The Required Time must be investigated in detail by observing the change of the estimated emotion while changing other conditions little by little.