

Robot behavior control system based on user's attitude using SCL*

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Abstract— In order to have simple conversations between users and companion robots, it is necessary that robots evaluate the user's attitude. We developed a robot behavior control system utilizing a user's skin conductance level (SCL). SCL is used as an indication of physiological arousal. This system controls the time the robot remains in one program based on the user's arousal level before changing topics. In the results, we found several tendencies of the user's response based on the SCL. We suggest a possibility for utilizing a user's physiological data to communicate with a robot.

I. INTRODUCTION

Robots will become common in our homes because of the development of robot technology. For example, there are Roomba [1], Droplet [2] and Litter-Robot [3] for household use. Roomba is an autonomous robotic vacuum cleaner. Droplet is a sprinkler system that combines the latest technology in robotics. Litter-Robot is a self-cleaning litter box for cats that uses a rotating globe to sift and separate clumps from the clean cat litter. In the future, we will begin to use these robots not only in homes but also in other locations such as schools, museums and shopping malls. On the other hand, robots other than those that help with human tasks are being developed to communicate with humans as companions. For example, Pepper [4], Hospi [5] and PARO [6] are designed to live with humans. Japanese mobile carrier SoftBank plans to start selling the Pepper robot next year. Hospi robots are currently operating at the Matsushita Memorial Hospital. PARO is the world famous therapeutic baby seal robot. There are various robots made for communication with humans in the world, however, these companion robots are not yet common in our daily lives.

We think that robots need to evaluate the user's attitude when living with humans in social environments. There are various methods for the evaluation of users including gesture, direction of gaze, physiological signals and so on. [7] Novak et al (2014) use some physiological measurements to estimate human workloads and effort in physical human-robot interaction. [8] In Dehais et al (2011) evaluations are made using physiological signals (electrocardiography, skin conductance, respiration, skin temperature) and gesture during interactions between humans and robots. [9] Prendinger et al (2006) investigated users' behaviors with animated interface agents using a physiological response (skin conductance and electromyography). [10] Some physiological

signals are used for various studies of human-robot interaction and so we also used physiological signals for the evaluation of a user's attitude. By analyzing the user's attitude based on physiological signals, many studies of HRI have utilized sensory presentation methods to elicit physical / mental conditions in real-time.[11],[12],[13] In these studies, the purpose of using the user's physiological signals is to detect and classify the emotional state of the user while executing tasks with a robot. Additionally, in several studies, robot behavior reflects the user's emotional state by analyzing physiological signals in real-time.[14],[15] These studies focused on the user's state of stress and/or anxiety to ensure quality in robot-assisted human work. Therefore, the aim of these studies is to develop a cooperative work robot as an assistant.

The goal of our study is to develop a sustained interaction between users and robots in a social environment. We propose a robot behavior control system reflecting the user's attitude in real-time. Our study focused on physiological arousal based on skin conductance levels (SCL). When arousal level is high the SCL value increases. On the other hand, decreased SCL value is related to boredom. [16] To evaluate the user's boredom is important in developing a sustained interaction between a user and a robot in a social environment.

Our system consists of two parts. One part is a prediction of the user's attitude by responding to the arousal level of the SCL, the other part is to control the time the robot remains in one program before the user's SCL decreases (boredom appears). To realize a user-centered robot behavior design we added the proposed system to an existing robot system. The robot has several modes programmed by the developer. For example, the robot developed for conversation with humans, some samples of the mode consist of the robot's movements and conversation topics (weather, hobby and so on). When the robot talks about weather (ex. mode1), the system confirms the user's attitude via SCR decrease, and it changes the topic to hobby (ex. mode2). The system monitors the user's attitude at all times and transmits the data to the robot behavior in real-time.

In this study, we evaluated the user's attitude during conversation with the robot from the SCL and a questionnaire of previous experiment and then proposed a model for the robot behavior control system. In the second experiment the proposed system was assessed via user trial. In both experiments the timing of the changes in the choice of subject (ex. subject1: today's temperature, subject2: humidity) in the mode (ex. mode1: weather) was caused by the experimenter using "Wizard of Oz."

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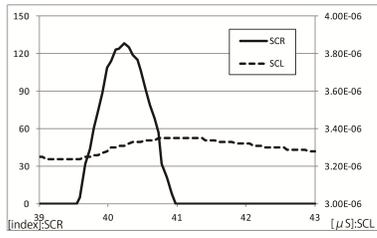


Figure 1. Typical waveform of skin conductance

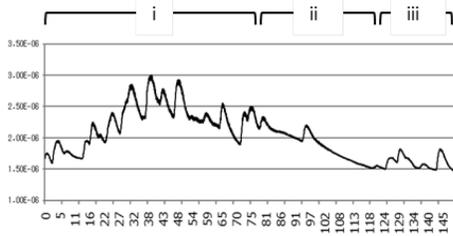


Figure 2. SCL during preliminary experiment

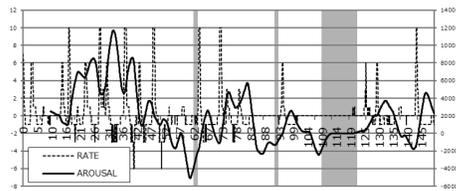


Figure 3. AROUSAL and RATE showing the SCL from Figure 2

II. SYSTEM CONFIGURATION

A. SCL: Skin conductance level

SCL signals indicate gradual change in skin conductance and are used to measure transitions from equilibrium to states of stimulation. Merrifield and Danckert (2014) reported that the physiological signature of boredom relative to sadness was characterized by rising HR (heart rate), decreased SCL, and increased cortisol levels. In addition this pattern of results suggests that boredom may be associated with both increased arousal and difficulties with sustained attention. [17]

SCL was measured using a device developed by Asahi Kasei Corporation. SCL data is acquired as a digital signal (16bit, sampling rate 20Hz) and transferred to a computer using Bluetooth transmission. We have provided an example of a typical signal trace in Figure 1.

B. Previous research

In our previous study, we verified whether the balance theory is established in a relationship between a human and two robots. [18] Balance theory, formulated by Heider [19] is a theory of interpersonal relationships among a person, another person, and an object (person or issue). Our system for this experiment auto-generates the scenario to establish a triadic relationship, and controls the two robots. The results show that the robots' behavior did influence the impressions humans had of the robots and that the balance theory was established. In one part of the experiment (part ii), two robots

start to talk with each other with the user just watching. At that time, 10 of 15 participants answered in their questionnaire that they felt "bored." Figure 2 shows the SCL average of 15 participants in the experiment. In part ii, the rate of decrease of SCL is the highest in this experiment. Actually, the rate of decrease of SCL in part ii is 8.50%, in other parts it stays the same or increases. The number of cases is small, but from these results it can be said that the user's "boredom" is related to SCL decreases.

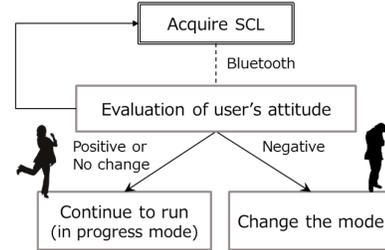


Figure 4. Outline of system

C. Recognition of user's attitude based on SCL

We proposed a formula for the recognition of the user's attitude (1). There are large differences among individuals of SCL, so we focused on the degree of inclination of SCL called RATE selecting a component that similar to the SCR (skin conductance response) known as GSR. The system recognized the user's boredom by satisfying the two conditions below.

- $AROUSAL(t) \leq 500$
AROUSAL introduce by follows.
($T_1=3sec.$, $T_2=10sec.$)
$$AROUSAL(t) = \sum_{t_2=t-T_2}^t \sum_{t_1=t_2-T_1}^{t_2} RATE(t_1)$$
 (1)
- The robot is ready to run. (2)

Figure 3 shows the result of recognition of user's attitude based on SCL of Figure 2 as RATE and AROUSAL. The system calculates AROUSAL and simultaneously monitors robot behavior in real-time.

The second condition (2) means that the robot has not finished a complete subject. The reason for this setting is to have the robot behave naturally when it changes the topic. An outline of our system is shown in Figure 4.

D. Robot behavior system

In this study, we used the interactive humanoid robot "Robovie-R Ver.3" that is designed for communication with humans. Robovie's height is 1080 mm, the width is 500 mm, the depth is 520 mm and the weight is about 35kg. Robovie has two eyes (2*2 DOF for gaze control), a head (3 DOF), two arms (4*2 DOF), touch sensors, a camera, a mike and a speaker. It also contains a CPU board so that it can be connected to a PC. We used two PCs: control PC placed within the robots, (RoboServer-PC), and the experimenter uses for remote control PC (Client-PC). In this experiment, the robots performed the scenario given by the system in order.

The current level of HRI technology poses problems, so we directed the robot's movements and speech only by way of the WoZ method.



Figure 5. Scene of the experiment

III. EXPERIMENT

We conducted simple experiments. The human-robot conversations about likes and dislikes were done using the above setting.

A. Experimental setting

17 Japanese Hokkaido University students of computer science between the ages of 20 and 25 (14 males, 3 females) participated in this experiment. They do not interact with robots regularly. We experimented in a room of Hokkaido University. During the experiment, the participants sat on a chair (see Figure 5). The experimenter controlled robots from a position that the participant could not see. Also, we video-recorded this experiment from behind the participants.

B. Experimental scenario

The robot has two modes.

- [Mode 1] greeting and questions (Table 1)
- [Mode 2] gratitude and gift (Table 2)

In Mode 1, the robot asks simple questions repeatedly. The robot responds "Right" every time after participants answer a question. When the system confirms the user's negative attitude via SCR decrease, it changes to Mode 2. Mode 1 is designed to bore the participants. Mode 2 is designed to interest the users by introducing a lot of robot movements and the added bonus of a gift.

C. Procedure

The experimental procedure is shown below.

- The experimenter tells the participant to interact with the robot if the robot speaks to him/her, and then moves out of sight.
- Robot begins to talk with the participant (See Table 1)
- The experimenter tells the participant to leave the room when the scenario of interaction is finished
- After that, the participant answers a questionnaire and is interviewed

In cases that a participant could not catch what the robot repeats the same subject using WoZ method.

TABLE I. CONVERSATION OF MODE 1

R: Nice to meet you. I'm Robovie.	
R: What's your name?	
P: <i>I'm [Participant's name].</i>	
R: That's a good name!	
R: Where are you from?	
P: <i>I come from [Laboratory or home address].</i>	
R: I see.	
R: Thank you for your coming. Nice to meet you.	
P: <i>Nice to meet you too.</i>	
R: Let's talk.	
R: Do you like dogs?	Repeat until system recognizes user's negative attitude via SCR decrease
P: <i>Yes I do.</i>	
R: Right.	
R: Do you like roller coasters?	
P: <i>Well.....No I do not.</i>	
R: Right.	

TABLE II. CONVERSATION OF MODE 2

R: Oh, by the way. There're gifts on the desk. (the robot points to the boxes)
Choose whichever one you like. I think the white one is best. Which do you prefer?
P: <i>The [white/black] box. (the participant chooses then takes the box)</i>
R: Thank you for coming. See you! (the robot waves its hand)

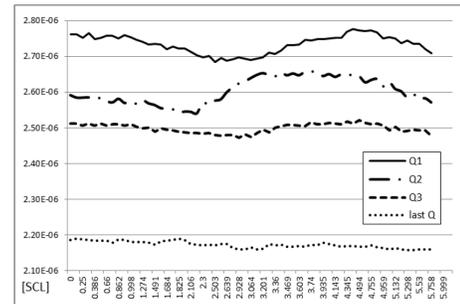


Figure 6. Average of user's SCL during the asking a question

IV. RESULTS OF EXPERIMENT

A. Users' SCL

The results of the average of user's SCL during the robot asking a question to participant shown in Figure 6. In this Figure, "Q1" is first question, "Q2" is second and "Q3" is third. "last Q" is last question before the changing Mode 1 to Mode 2. The users' SCL decreases by repeating questions is confirmed. The system could not change to Mode 2 with two participants. Despite feeling bored one participant's SCL did not decrease during the experiment. This was because the electrodes picked up noise from the participant's hand movements and distorted the SCL. The other participant, answering questions in the interview, said she really enjoyed conversation with the robot. Figure 7 & 9 show the point of mode changes from Mode 1 to Mode 2. (Fig.7: 15 participants, Fig.9: 4 participants). In the case of Figure 7, after the robot changes a mode, the average of SCL increases significantly.

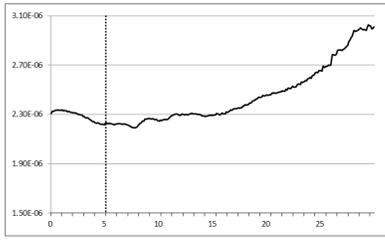


Figure 7. The average of SCL of all participants in the point of mode changes

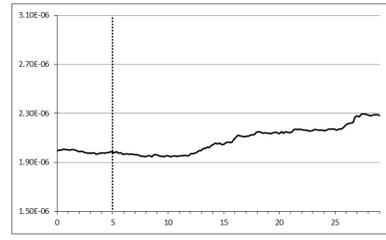


Figure 9. The average of SCL of the users who felt bored in the point of mode changes

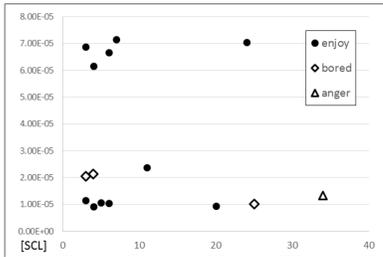


Figure 8. The relationship between the average of SCLs and number of the robot's questions

TABLE III. RESULT OF QUESTIONNAIRE ABOUT IMPRESSION

Users' impression	Enjoyable	Boring	Angry
Number of participant	12	4	1

It can be said that SCL decreases in experiments are caused by not only boredom but also habituation and SCL increases when the topic is changed. These results indicated the usefulness of SCL for interaction with the robot.

B. Users' impression in questionnaires

Table 3 is user's impression of conversation with the robot in a questionnaire and interview. Many participants had positive impressions. Twelve participants enjoyed this experience without losing interest. Four felt bored. Our system detected two of four participants' boredom in the early stages. However, the system misunderstood the attitude of the other two participants. Another one of the five participants was angry about the robot's response, "Right." It was known that anger elicited a significant increase of frequency of SCR [20], it links to increase of RATE in our proposed system. Then, the system incorrectly recognized user's attitude by increase of RATE. It is necessary to add new conditions about RATE analysis to address a wide range of user's attitudes.

C. Relationship between SCLs and users' impressions

The average number of the robot's questions is 10.4 when Mode 1 finished. Figure 8 is the graph representation of relationship between the averages of SCLs and the number of the robot's questions. There are large differences among individuals of SCL as explained above. It is difficult to set the threshold value for detecting user's attitude. These results show that the proposed system is useful for detecting user's attitude based on AROUSAL.

V. FUTURE WORK

Many people wear wrist-watch type devices that connect to smart phones and have many uses. These smart watches are usually equipped with a pulse rate sensor and the system will be able to get the user's status via the bio-signals from the wearable device. We think we can use a virtual agent on a display in place of a robot. For example, this system can be used for department stores and science museums. In the case of the information desk of a department store, when the robot introduces a new item A, the system confirms the user's attitude via arousal level decrease from existing devices, and it changes the topic to item B. In the case of an exhibition in a science museum, the robot curator explains about exhibit A, when the system confirms the user's negative attitude via arousal level decrease, it changes to exhibit B.

VI. CONCLUSION

In this study, we proposed a robot behavior control system based on user's attitude using SCL. We conducted simple experiments to evaluate our system. From the results of the experiments, 12 of 17 participants did not get bored in spite of the simple behavior of the robot. Additionally, SCL decreases were caused not only by losing interest but also by habituation and SCL increases when the topic was changed. In this system, we focused only on "boredom," but there are many interpretations of this word. We need more participants and to improve our proposed system. For future work, we plan to analyze impressions by other physiological factors such as skin temperature and pulse.

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