Process of Agency Identification Based on the Desire to Communicate in Embodied Interaction

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ABSTRACT
Humans can communicate because they adapt and adjust their behavior to each other. We hypothesize that developing a relationship with others requires coordinating the desire to communicate and that this coordination is related to agency identification. To model this initial phase of communication, we created an experimental environment to observe the interaction between a human and an abstract-shaped robot whose behavior, moving on the floor and rotating, was mapped by another human. The participants were required to verbalize what they were thinking or feeling while interacting with the robot. At present, we do not have a sufficient number of participants, and experiments and data analysis are ongoing. We must verify the effects of interaction patterns and inspect what type of action and reaction are regarded as signals that enhance interpersonal interaction.

Author Keywords
Interaction; agency; communication relationship;

ACM Classification Keywords
H.1.2. User/Machine Systems: Human information processing

INTRODUCTION
Humans have the social ability, such as theory of mind, to adjust their behavior according to the behavior and mental states of others [9]. In addition, to behave without being affected is an important adjustment in our social life, exemplified through situations such as passing someone in a crowd or sitting next to a stranger in a public space. The behavior of objects, on the other hand, is normally regarded as inanimate or lacking emotion. Despite this, we often treat computers as agents [10]. Whether or not we recognize others or objects as agents, which have a mental state and are able to regulate their own behavior, depends on actual interaction. Some research also indicates that social cognition is embodied interaction [4, 2]. In this study, we hypothesize the process of interaction that develops into interpersonal relationship as the initial phase of communication and try to model it.

Human-human communication, such as language, facial expression, gaze, gesture, posture, and spacing, is carried out intricately and simultaneously. To model the process of establishing a relationship, we need to narrow these elements down to one simple element. Humans manipulate distance between others based on context or relationship [5]. Approaching someone normally indicates a level of interest in that person. Spatial interaction is observed in many animals; therefore it appears to be a primitive and basic interaction. Thus, we focus on spacing coordination as a starting point to simplify modeling. Research on minimum interaction indicates that people recognize other people without cues provided beforehand because of our ability to form extemporaneous joint action or turn-taking with each other [1, 6]. However, little research has been done on interaction when the participants have no prior knowledge of or context for, such as experimental tasks, the interaction partner. These participants attempt to interact with their partner from the beginning because they are motivated to complete tasks. We assume that the initial phase of communication has the aspect of participants coordinating interest in or wanting to communicate with their partners. We need to consider the situation in which participants are able to ignore their partner's behavior or are not interested in the partner. Our experiment is carried out with no instruction about interaction with the partner. In order to clarify how people behave and coordinate relationships in the initial phase of communication, we conducted an experiment in which the participants interact with an ostensibly unknown artifact whose behavior actually mirrors another participant's movement. By modeling this process, artifacts, such as a robot, become able to form relationships adaptively with humans, estimate human desire to communicate, or display a specific pattern of notification of communication.

INITIAL COMMUNICATION PHASE
In this section, we describe our concept of the initial communication phase and our research method. We assume that the initial communication phase has two aspects: mutual behavioral coordination depending on the desire to communicate and the process of agency identification. Interaction between

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humans and encountering entities that possess physical bodies always is affected, even if the entities do not move at all. Despite this, we are able to ignore entities that are irrelevant to us. We assume that embodied interaction is carried out subconsciously before initiating conscious interaction (Figure 1). In this subconscious interaction, some specific pattern or message causes human cognitive activity to be concerned about the entity's mental state. This interaction then progresses to the next phase in which both actors coordinate their desire to communicate with each other. As an example, when we need directions in an unfamiliar place, we look for someone to ask by gazing at or approaching a person we believe can help. Naturally, we can direct this signal depending on our own desire to communicate.

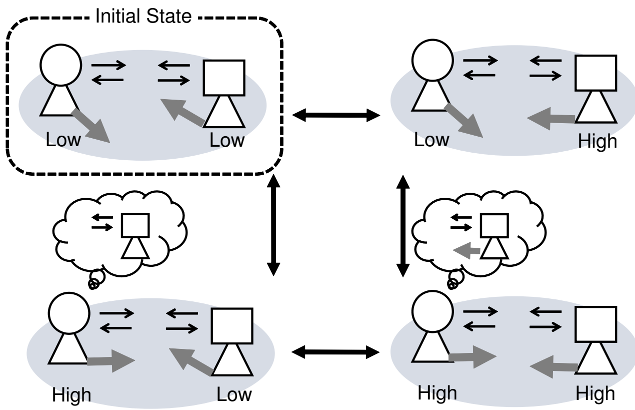

Figure 1. State of desire to communicate

In human communication, we can immediately identify human partners. The human brain possesses an area that is specifically designed to detect the human body [3]. In addition, as the phenomenon of "biological motion" illustrates [7], we have a specific perception for recognizing human body movement. On the basis of these abilities, other people are regarded as agents with which we can communicate. On the other hand, artifacts, especially non-humanoid, non-animal, or abstract-shaped robots, must build a social relationship beyond just being objects (Figure 2). The artifacts' behavior must convey to human abstract thinking that their motions contain some intention or meaning. We hypothesize that some interaction pattern or joint action formed subconsciously on the physical level acts as a signal. Because the interaction partner has been already recognized as an agent, this does not continue. When interaction collapses, the partner seems to be regarded as an object. We assume that a social relationship can repeatedly form and collapse through interaction.

A think-aloud method is useful for investigating changes in mental states regarding an object. Without clues, it is difficult to segment physical interaction. By getting participants to speak about their thinking or feelings during interaction, we can identify the interaction and the development of recognition of the interaction partner can be observed. We also aim to detect any cues that indicate that the object is being perceived as an agent with a mental state.

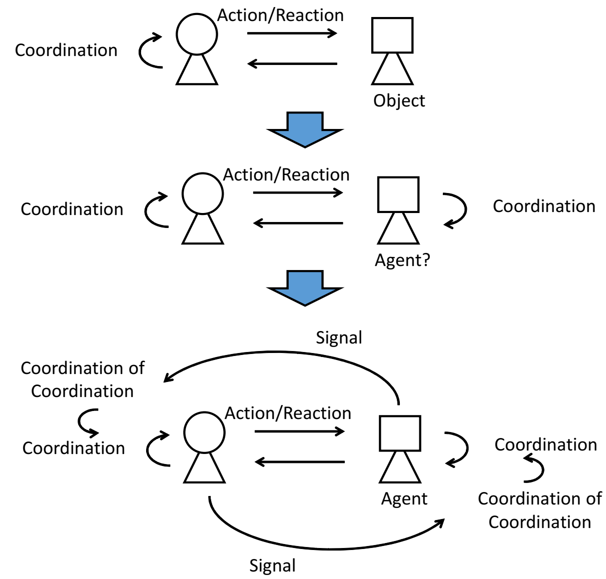

Figure 2. Agency identification

PREVIOUS EXPERIMENT

In our previous study, we conducted an experiment in which the participants interacted with a robot that had only one function: moving on the floor. Synchronizing motion is possibly a cue to start recognizing a robot as an agent (Figure 3). Some research indicates that synchronization of behavior between humans occurs unconsciously and is necessary for joint action with others [8, 11]. Thus, we can conclude that synchronizing motion with objects causes a phase shift from the initial phase in our hypothetical model. However, whether behavior including synchronization is accidental or not is unclear and difficult to determine from our previous experiment. Furthermore, it is too difficult for us to identify the desire to communicate because we confuse the mutual coordination of desire and the process of identification of agency, such as testing the regularity of behavior. To solve this problem, in this study, we use a robot that can perform a rotating motion in addition to moving about the floor. In this way, behaviors can obviously indicate whether the robot can think or not and whether it desires or doesn't desire to form a relationship.

EXPERIMENT

In this section, we describe the details of our experiment for investigating the process of how people realize that an interaction partner has the ability to construct a communication relationship and wants to establish a relationship with them. We observed interaction between humans and robots. It is difficult for participants to recognize that a robot's motion corresponds with another participant's motion without interaction. However, the robot's behavior is certainly capable of building an interpersonal relationship through interaction. Therefore, we observed the interaction between a human and a robot that was not previously perceived as an agency, but behaves as an agent. In addition, we observed the interaction between participants who know that the robot points to the places and directions of another human for comparison. We acquired the

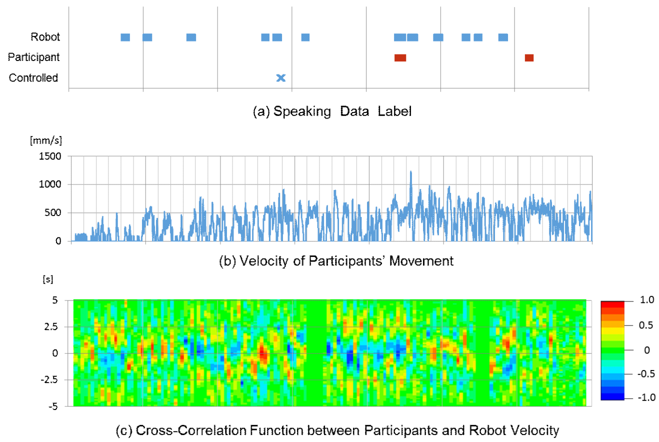

Figure 3. Results of previous experiment

participants' mental state data using a think-aloud method. Our aim was to model the process of creating an interpersonal relationship from the utterance data and behavioral data. At present, we do not have a sufficient number of participants, and experiments and data analysis are ongoing.

Method

Apparatus

As shown in Figure 4, two rooms were used as the experimental environment. Both rooms were constructed with similar equipment. A three meters in diameter circle constituted the delimited field of the participants' movement. In both rooms, the positions and orientation of the participants were mirrored by robots in another room. That is, the position and orientation of the robot located in one room mapped the position of the participant in the other room. In this way, each participant was able to interact with the other participant without being aware of each other. We used a robot with three omni wheels that is able to move in any direction (Figure 5). We controlled the robot via Bluetooth. The robot's position was calculated by encoders and corrected by image processing through a video camera. Orientation was measured by a magnetic field sensor. The robot was covered with an outer case. The participants wore a headset and voice recorder for utterance data gathering. The participants' positions were measured with a laser rangefinder (URG-04LX, Hokuyo Automatic Co., Ltd.). The participants' orientation was measured with a smartphone compass (Nexus 5X) attached to the waist and the data was sent to another room by socket communication.

Task and Condition

The participant pairs were guided into the rooms separately without knowledge of their respective partners. Before interacting with the robot, the participants practiced thinking aloud. They were required to speak about anything they felt or thought while working on a puzzle called a tangram. The participants were then instructed to move freely within the delimited field circle and to voice their feelings or thoughts. At this phase, two types of instructions were given to the participants; some were not told about the robot's behavior, while

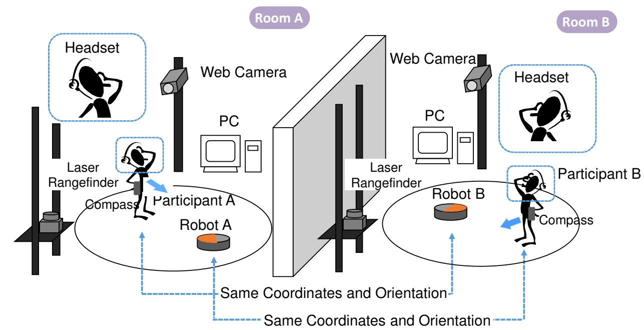

Figure 4. Experimental setup

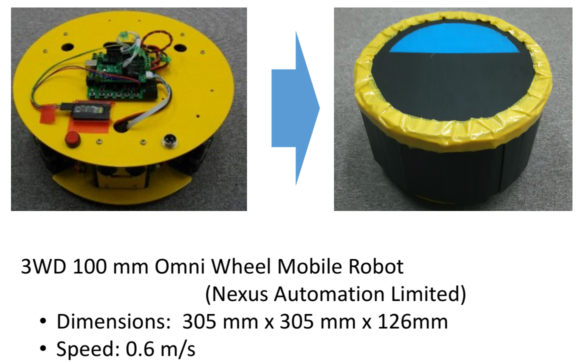

Figure 5. Appearance of robots

the others were told that the robot's movement mirrors the other participant's position. They were also told that their position was conveyed to their partner through a robot in another room in the same manner. In this experiment, we set two types of pairs; some pairs consisted of non-instructed participants, while the other pair consisted of instructed participants. All of the participants were told that they were under no obligation to do anything with the robot and that they could spend their time freely in the field. Each participant was left alone in the room, and the interaction between the participants and the robot was observed for seven minutes (Figure 6). The participants then responded to questionnaires.

Our experiment was conducted under two conditions: instructed participant pairs and non-instructed participant pairs. It is presumed that instructed participants interact with the robot depending on their desire to communicate because the robot is understood to be an agent. On the other hand, non-instructed pairs would characterize the robot behavior according to their interest. By comparing these conditions, we can distinguish agency identification with the mutual coordination of desire to establish a relationship.

Observed Data

We observed and analyzed the following data:

- Behavioral data
  - Log data of participant position and orientation (every 125 ms)

Figure 6. An interaction scene

- Log data of robot position and orientation (every 125 ms)
- Interaction video

- Speaking data
- Questionnaires
  - Free descriptions about behavior of participant and robot

Analysis

We assume that the characteristic of interaction between participants and robots differs depending on their desire to communicate and identification of agency. When both members of the participant pair do not care about the robot, involuntary synchronization will occur, which can be detected by the velocity of the cross correlation function (CCF). The CCFs are given by

$$f(k) = \frac{Cov(A_t, B_{t+k})}{\sigma_{A_t}\sigma_{B_{t+k}}} \quad (1)$$

where $Cov(A_t, B_{t+k})$, σ_{A_t} and $\sigma_{B_{t+k}}$ denote the covariance and standard deviation. When the CCF peaks appeared near zero, the participant and robot moved simultaneously. When the participants dared to ignore the robot, the peaks of CCF possibility deviated from near zero.

When the participants were interested in the robot, the orientation of their body changed according to the robot's position. Thus, the desire to communicate with the robot can be represented by the body direction toward the robot. The angular correlation coefficients are given by

$$\rho_{cc} = \frac{\sum_i \sin(\alpha_i - \bar{\alpha})\sin(\beta_i - \bar{\beta})}{\sqrt{\sum_i \sin(\alpha_i - \bar{\alpha})^2 \sum_i \sin(\beta_i - \bar{\beta})^2}}. \quad (2)$$

When both of the participants want to interact with the robot, their movement can be complicated. In this phase, it appears that an impromptu interaction pattern arises. We examined some indicators, such as the Granger causality test. These indexes of the interaction phase will be compared and checked by the speaking data.

CONCLUSION

In this study, we focused on an initial phase of communication and assumed that this phase has two aspects-the process in which participants perceive objects as agents and the mutual coordination of the desire to communicate-based on the results of our previous experiment. To make these processes more obvious, we observed the interactions with an abstract-shaped robot whose positions were mapped by other participants. Our experiment also included an instructed and non-instructed condition regarding the robot's actual behavior. We will investigate cues during such progress. Modeling this interaction process must await further, ongoing investigations.

Acknowledgments

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