Colony agent: Tactile feedback device that evokesa unified feeling with the agent

Yusuke Kanai[1], Wongphati Mahisorn[1], Hirotaka Osawa[2] , and Michita Imai[3]

[1] Graduate School of Science and Technology, Keio University
[2] Information and Systems, University of Tsukuba
[3] Faculty of science and Technology, Keio University

Abstract: This paper presents the concept of a new type of human-agent interaction (HAI) called a colony agent. The colony agent shares their tactile sensations with the users through vibration stimuli, and allows the users to intuitively notice their surrounding environment through multi-modul sensations, visual perception, and tactile stimuli. In this way the users interact with not only their own environment but also the agents environment. Furthermore, users can communicate and work more cooperatively by recognizing the agent's behavior based on what it is seeing, touching or doing. The goal of this concept is to more effectively support any tasks that users communicate and work collaboratively with agents. In this paper, we provide three examples showing the capability of this research.

1 Introduction

"Body schema"[1][2] is a human cognitive ability that allows people to know where is their body parts are and dynamic and kinematic informations, e.g., their joint angles. Body schema enables us to brush our teeth, scratch our back, and wash our own body. When their body schema is damaged, patients may experience phantom limb pain, even if the limb has been amputated[3].

Body schema is plastic and flexibile. For example, when we want to pick something up that has been dropped into a narrow slot, we may use a thin rod and hook to grab the object. Because we can sense when the rod touches the object our body schema is considered to expand from our own body to the rod. Iriki[4] demonstrated a macaque monkey retrieving distant objects using a rake, and showed that its body schema was modified and extended to the rake. Yamamoto[5] experimented with subjects holding a stick in each hand with their eyes closed. Successive stimuli were deliverd to the tips of each sticks. The subjects were then asked to judge the temporal order of these two successive stimuli. In the experiment, Yamamoto compared four conditions: crossing of the arms with the two sticks also crossing, uncrossing of the arms with the two sticks crossed, crossing of the arms with the two sticks are uncrossed, and uncrossing of both the arms and the two stickes. He observed whether the subjects could respond to the stimuli correctly. The result of the experiment showed that the body schema of the subjects was expanded to the two sticks. When crossing their arms and uncrossing the two sticks ,and uncrossing their arms and crossing the two sticks, their error in judgment increased. On the other hand, when uncrossing both their arms and the two sticks, and crossing both their arms and two sticks, their errors in judgement were low and at nearly the same rate.

We consider such expansion of a body scheme to be evoked by multiple sensations, i.e., visual and tactile perception[6][7][8]. Botvinics and Cohen[9] showed that the perception of tactile senses can be transferred to a rubber hand. In their experiment, while a rubber hand placed in fromt of them was being stroked with a paintbrush, the subjects also had their real hand stroked at the same point simultaneously while watching the stroking. This illusion, in which the subjects felt the rubber hand to be their own hand, is officially called the “rubber hand illusion,” and many researchers have been researching this phenomena (e.g., [10][11][12]). Ehrson demonstrated another rubber hand illusion using a full body[6]. In his experiment, the subjects were asked to sit while wearing a head mount display, upon which images from a camera located at the their backward was appeared. He touched their actual chest using a plastic rod and simultaneously moved another rod at just below the camera as if the rod touching a phantom chest.

After the test, the subjects reported that they got an illusion of sitting behind their actual body and looking at their own back. As just described, These are just a few examples of how one can modify the human body schema through visual perception and tactile stimuli.

Previous studies on body schemas have been restricted to non-agentive objects and there is currently no mention of cases in which a human body schema includes an object possessing an agency. The definition of an agency remains ambiguity, although their common property such as reactivity, autonomy, communicability, flexibility and social ability are considered[13]. Tsakiris, et al.[14] described an agency as “the sense of intending and executing actions, including the feeling of controlling one's own body movements, and, through them, events in the external environment.” Yamada defined an agency as an autonomous system that can interact with the external environment including humans[15]. In this paper, we define an agent as an autonomous or semi-autonomous system that can interaction with humans by using or imitating human communication manner, e.g., voice and gestures. It has descrived that it is uncertain whether a human body schema can be included as an object with an agency. However we think that giving multiple sensory perceptions including visual perception and tactile presentation enables the expansion of body schema including a object with an agency. Research by Slater's paper [16] and Nishio's paper [17] support this idea.

This paper presents a concept of a colony agent: sensations or perceptions of an agent shares with a user, and then the user's body schema expanding their own body to the agent's body. We introduce three examples to illustrate the possibility of colony agent and the possible effection by sharing the agent's perception with the user. This paper is not intended to clear a novel attribution of the colony agent. The presenting paper's goal is to propose as a branch of HAI to make more cooperative communication of users and agents.

2 Design Concept of Colony Agent

2.1 Related works

The key components in modifying a user's body schema are visual and tactile perception. In research on the rubber hand illusion, asynchronous tactile and visual perception was shown to greatly reduce the illusion [9][12][18][19]. A delay of approximately 500 ms is enough to reduce the illusion.

A body schema can be remapped to an anthropomorphic agent or a character[20][16][17]. Slater showed that humans can transfer ownership to an entirely virtual body[16]. Nishino verified whether humans can transfer their sensation to a controlling android robot, and showed that when the human can control the robot with little delay, the humasn will feel as if their body ownership has been transferred to the robot[17].

2.1 Implementation

Based on these related works we implemented a device that helps users feel an agent's sensation of touch. An overview of a colony agent shows in Fig. 1. This agent is the Robovie-mR2, which was developed at ATR, and to it we added fourteen touch sensors: four sensors for the head, four sensors for the body (two for the front side and two for the rear side), and three sensors for each arm. The user who shares a touch perception with the agent wears a haptic glove (Fig. 2), which is equipped with 14 vibration motors. Each motor corresponds to a touch sensor equipped on the agent. The user also wears a display device, such as a smart watch, which allows them to view the behavior of the agent.

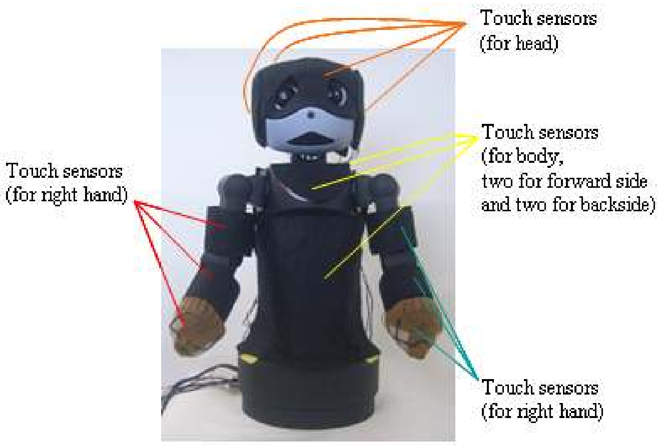

Fig. 1 An example of a colony agent (Robovie-mR2), equipped with 14 touch sensors

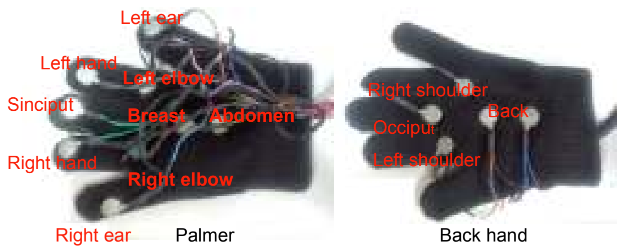

Fig. 2 Haptic glove equipped with 14 vibration motors, with each motor corresponding to one of the colony agent's touch sensors

3 Examples of Human and Colony Agent Interaction

This section describes three examples: a child-rearing agent, an experimental design used to discover a suitable agent behavior through visual and touch perception, and an entertainment agent.

3.1 A colony agent for nurturing babies

Double-income families are often faced with the problem of taking care of their babies or children while at work. Many such families tend to leave their children at a day-care center or hire a babysitter. However, parents often worry about how their children are being nurtured.

A colony agent can apprise such parents of how their children are doing. To nurture a child, it is expected that the colony agent interact with the children through touch. The parents can observe the touching interaction by wearing a haptic glove. If they are anxious about what the child and agent are doing, they can watch the display worn on their arm.

Such usage ability is due to the advantage of directly delivering touch information to the glove wearer.

3.2 An experimental method for upgrading the HAI design

This experimental design was inspired by an immersive discovery method[22]. The design of an agent's behavior is usually based on human-human interaction. However, it is not always true that a human interacts with an agent in the same manner as another human. Agent interaction should therefore not always be based on human interaction.

A colony agent allows experimenters to observe how a subject and the agent interact and to recognize a touch interaction intuitively. Furthermore, the area of the body the experimenter should pay attention to is restricted to the right or left hand, and thus if the experimenter has to control the agent while paying attention to its touch sensation, the experimenter's attention will not be disrupted

The experimental process is likely to be as follows. We assume that the goal of the experiment is to clear the appropriate agent's behavior during a particular communication event, including a touch interaction. Experimenters preliminarily implemented some required actions for the agent. In the experiment stage, the agent communicates with the subjects based on the action implemented. The behavior of the agent is generated autonomously, but if needed, the experimenter can order or operate the agent to behave in a certain way. Under this experimental environment, the experimenter can observe and control the interaction of the subject and the agent by recognizing a touch sensation, and can explore more necessary actions of the agent from visual and touch information.

3.3 Homuncular flexibility in the real world

Homuncular flexibility was proposed by J Ranier. According to [23], homuncular flexibility is a technical design that supports users to learn "to remap physical degrees of freedom onto digital representations in interactive tasks." The first trial of homuncular flexibility was demonstrated by Lanier and Ann. In their experiment, the subject wore an HMD in order to feel like to be a virtual lobstar. Homuncular flexibility has recently attracted the attention of researchers studying virtual reality. Slater developed an extended virtual human[24], which is related to the concept of homuncular flexibility.

Our proposed concept of a colony agent is also related to homuncular flexibility. Although the previous works related to homuncular flexibility have been restricted to virtual events where the user's body schema is remapped to a virtual avatar, our proposed concept tries to extend homuncular flexibility to include a real-world agent.

We believe that a colony agent can also be used for entertainment purposes. By allowing two colony agents to interact with each other through touch, such as mimicking a boxing match, a touch sensation can be delivered to each user wearing a haptic glove. We believe that sharing such a touch sensation will induce each user to increase their attachment to their agent. Users will then further engage with and become more interested in HAI.

4 Discussion

We proposed a colony agent as a branch of HAI. The property of a colony agent is to deliver a touch sensation of the agent to the user through the glove. We developed a colony agent prototype equipped with 14 touch sensors, and a glove equipped with 14 vibration motors driven by the corresponding touch sensors. The wearer of the glove can check whether the motor vibrations are synchronized to the reaction of the touch sensors. We expect that synchronizing the visual and touch perception enables the body schema of the glove wearer to extend to the agent's body. The example of homuncular flexibility illustrated in subsection 3.3 is one application related to a body schema.

The two examples in subsections 3.1 and 3.2 describe applications using the property of delivering a touch information directory. Although many researchers are interested in gathering human behavior or physiological information to make a cooperative interaction between humans and an agent, there have been few design studies on how to deliver an agent's actions, behaviors, and internal status to humans. Of course, humans can check such information through visual perception, even for an internal status, which can be expressed through emotion. however we believe that derivering such agent's information also make a more cooperative interaction. We think that one should re-consider the agent's manner of communication in terms of cooperation.

It is expected that a colony agent will be dealt with as the user's own possession or body. An agent such as a robot is likely to be dealt with as the user’s possession. We therefore expect that the user will feel a greater sense of attachment, familiarity, and sympathy with the agent.

5 Conclusion and Future work

This paper proposed the concept of an HAI branch called a colony agent. A colony agent is equipped with touch sensors placed on several areas of the body. These touch sensors transmit human tactile perception through a wearable device.

We developed a particular colony agent equipped with 14 touch sensors, and a glove equipped with 14 vibration motors corresponding to the agent's touch sensors. We plan to engage in further research on colony agents using this glove.

We introduced three practical examples of the proposed concept. In two of the examples, we describe the collaboration between a human and agent based on a sharing of the agent's touch perception. The remaining example is on entertainment using the property of a body schema.

We expect that users will likely become more attached to a colony agent through sensation sharing, which can create feelings of intimacy and empathy. In the future, we will conduct an experiment to identify and verify this hypothesis.

References

[1] Gallagher S.: Body schema and intentionality, Bermudez, J. L.(Ed) et al., The Body and The Self, MIT Press (1998), pp.225-244.

[2] Haans A., and IJsselsteijn W. A., Embodiment and telepresence: Toward a comprehensive theoretical framework. Interacting with Computers. (2012).

[3] Ramachandran V. S. and Blakeslee S.,: Phantoms in the Brain, Quill William Morrow, 1998.

[4] Maravita A., and Iriki A., Tools for the body (schema). Trends in cognitive sciences, 8(2), pp. 79-86 (2004).

[5] Yamamoto, S., & Kitazawa, S.,: Sensation at the tips of invisible tools.Nature Neuroscience, Vol. 4, No. 10, pp. 979-980 (2001)

[6] Ehrsson, H. H.,: The experimental induction of out-of-body experiences., Science 317.5841, p. 1048 (2007):

[7] Armel, K. Carrie, and Vilayanur S. Ramachandran. ,Projecting sensations to external objects: evidence from skin conductance response., Proceedings of the Royal Society of London. Series B: Biological Sciences 270.1523, pp. 1499-1506. (2003)

[8] Angelo M., Spence C., and Driver J., Multisensory integration and the body schema: close to hand and within reach., Current Biology 13.13, pp. 531-539 (2003)

[9] Matthew B., and Cohen J., Rubber hands' feel' touch that eyes see., Nature 391.6669, pp. 756-756 (1998).

[10] Tsakiris, M., and Haggard, P., The rubber hand illusion revisited: visuotactile integration and self-attribution., Journal of Experimental Psychology-Human Perception and Performance, 31(1), pp. 80-91(2005).

[11] Kammers, M. P. M., de Vignemont, F., Verhagen, L., and Dijkerman, H. C., The rubber hand illusion in action. Neuropsychologia, 47(1), pp. 204-211. (2009)

[12] Ehrsson, H. H, Charles S., and Richard E. P., That's my hand! Activity in premotor cortex reflects feeling of ownership of a limb., Science305.5685, pp. 875-877. (2004)

[13] Franklin, S., and Graesser, A.. Is it an Agent, or just a Program?: A Taxonomy for Autonomous Agents. In Intelligent agents III agent theories, architectures, and languages (pp. 21-35). Springer Berlin Heidelberg (1997).

[14] Tsakiris, M., Prabhu, G., and Haggard, P., Having a body< i> versus</i> moving your body: How agency structures body-ownership. Consciousness and Cognition, 15(2), pp. 423-432. (2006).

[15] S. Yamada, Designing “space” between human and robot (in Japanese). Tokyo Denki University Press, (2007).

[16] Slater, M., Spanlang, B., Sanchez-Vives, M. V., and

Blanke, O.. First person experience of body transfer in virtual reality. PLoS One, 5(5), e10564. (2010)

[１７] Nishio, S., Watanabe, T., Ogawa, K., & Ishiguro, H.. Body ownership transfer to teleoperated android robot. In Social Robotics (pp. 398-407). Springer Berlin Heidelberg. (2012)

[１８] Tsakiris, M., Hesse, M. D., Boy, C., Haggard, P., and Fink, G. R., Neural signatures of body ownership: a sensory network for bodily self-consciousness. Cerebral Cortex, 17(10), pp. 2235-2244. (2007)

[１９] Shimada S., Fukuda K., and Hiraki K., Rubber hand illusion under delayed visual feedback., PLoS One 4.7: e6185. (2009).

[２０] Petkova, V. I., and Ehrsson, H. H., If I were you: perceptual illusion of body swapping. PLoS One, 3(12), e3832. (2008).

[２１] Steptoe, W., Steed, A., & Slater, M. Human Tails: Ownership and Control of Extended Humanoid Avatars. Visualization and Computer Graphics, IEEE Transactions on, 19(4), pp. 583-590. (2013).

[２２] Osawa, H., and Imai, M.. Immersive Discovery Method for Exploring Interaction Strategies of an Agent (Jap). Transactions of the Japanese Society for Artificial Intelligence, 28, pp. 160-169 (2013).

[２３] VHIL: Virtual Human Interaction Lab, http://vhil.stanford.edu/projects/#homuncular