MUTUAL ADAPTAION IN COMMUNICATION BETWEEN A HUMAN AND A LIFE-LIKE AGENT BY SHARING CONTEXT DEPENDENT FACIAL EXPRESSIONS

*Tomohiro Yamaguchi, *Yuta Ochi, **Seiji Yamada

*Dept. of Information Science, Nara National College of Technology
**National Institute of Informatics

ABSTRACT

This paper describes a human-agent interaction in which a user and a life-like agent mutually acquire the other's mind mapping through a mutual mind reading game. In these several years, a lot of studies have been done on a life-like agent. Through development of various life-like agents, a mind like emotion, processing load has been recognized to play an important role in making them believable to a user. For establishing effective and natural communication between an agent and a user, they need to read the other's mind from expressions and we call the mapping from expressions to mind states mind mapping. We propose a mutual adaptive interaction between a human and a life-like agent. In our framework, a user plays a mutual mind reading game with an agent and they gradually learn to read the other's mind through the game. Eventually we make experiments to investigate its effectiveness.

1. INTRODUCTION

In these several years, a lot of studies have been done on a life-like agent like a Microsoft agent [1], an interface agent [2]. A typical life-like agent appears on a Web shopping page and supports a user in inputting his/her order. Through the development of various life-like agents, an agent's mind (i.e., computational internal states of an agent) like emotion, processing load has been recognized to play a very important role in making them believable to a user [3]. Besides, expressions of minds are also effective to computer-mediated communication. However, even if a mind mechanism is fully implemented on a life-like agent, there is a significant problem that to recognizing a partner's mind state between a user and an agent is difficult.

For establishing effective communication between a life-like agent and a user, they need to be able to identify the other's mind from an expression and we call this task *mind reading*. Note that mind is a set of internal states those are non-observable directly. If mind reading is impossible, they can't act human-like behaviors those significantly depend on the other's mind states. For example, a life-like agent should kindly and carefully behave to a depressed or busy user, and intuitively communicate its processing load to a user through a facial expression. Though mind reading is always done among human, it between a life-like agent and a user becomes far more difficult. The reason is that design of agent's expressions significantly depends on personal preference, or social culture. For example, Fig.1 shows various expressions and corresponding minds of Microsoft agents. We can easily identify minds from some expressions (Surprised, Congratulate for authors), however minds from some expressions (Confused, Decline, Process for authors) may be hard to be identified. Consequently a life-like agent and a user need to acquire relation between an expression and a mind when they actually encounter. We call such a mapping from an expression to a mind a *mind mapping*. Major difference between a mind and an expression is whether directly observable or not.

Fig.1 Various expressions of Microsoft agents.

To deal with the mind mapping task, we have proposed a human-agent interaction framework in which a user and a life-like agent mutually acquire mind mappings each other [4,5]. They play *a mutual mind reading game* together and gradually learn mind mappings each other. Instance-based learning is applied to agent's learning. However, there is a major problem of mutual learning that one's learning affects the convergence of the partner's learning. This also occurs in human agent interaction when they try to learn the partner's mind mappings.

To solve this, this paper presents a mutual adaptive interaction with context sharing between a human and a life-like agent that considers learning ability of a human user. The main idea is *context sharing* through an interaction between an agent and a user. When they notice

and share the common rules as the context of the interaction, we call this *context sharing* that makes the mutual learning easier. Major mutual learning problem is that each learning behavior or result may affects or interferes with other's learning since they interact each other to learn [6]. The context is a constraint to reduce or to avoid the mutual learning problem in the mutual adaptive interaction. The shared context guides each learning properly as the constraint in the mutual learning.

In this paper, we show the experimental results on a mutual mind reading game with the fixed context of an agent and with a random context of an agent. In that, when a user adapts the agent that expresses the emotion that depends on a game context, the learning task performance of the user is improved. Then the consistency of the user's expression is also improved, this makes agent learning easier. At last, their communication will go better.

2. MUTUAL ADAPTATIVE INTERACTION

2.1 Overview of the mutual adaptive interaction

The mutual adaptive interaction is an interaction that not only deals with an agent's adaptation for a user but also considers the user's adaptability to the agent. Major difference from adaptive interaction is that whether considering a human user's learning behavior or not. For the mutual adaptation, it is important that both an agent and a user share the same context through their interaction. The reason is that if a behavior of the agent in the interaction depends on the context, a user can adapt easily by recognizing the way of the context dependence. This will make the user's cognitive load lower. Therefore, for the agent's adaptation with adaptability, it is important that the agent follows a simple context that a user can follow easily. In this paper, context means the tendency of mind state transitions in n times through a mind mapping game.

2.2 Conditions those occur mutual adaptation

We assume the conditions to occur the mutual adaptation between an agent and a user as follows:
1. An agent should behave regularly that is easy to be followed by a user.
2. A user does not need to do a useless teach that affects the agent's learning.

The key points are those the context following behaviors may reduce the user's cognitive load, and they make the partner's behavior learning easier each other.

2.3 Task: the mutual mind reading game

This section describes a *mutual mind reading game* in which a user and a life-like agent try to recognize the other's mind state through the other's (facial) expression as the learning task of a mind mapping. They mutually answer their results on the other's mind, and one having a correct answer gets a score. This game is designed to acquire mind mappings each other so that a user may enjoy it, and as results, the user's cognitive load is reduced.

A game in which a player estimates the other's mind state through the facial expression to compete for the accuracy is called a *mutual mind reading game*. "Mutual" means that both a game in which an agent estimates a user's mind from his/her expression and a game in which a user estimates an agent's mind from its expression are performed *in turn*.

A primary objective of a game is to learn mind reading between an agent and a user. Therefore, both an agent and a user play a game with fixed mind mappings each other. For a user, a main objective of the game is to learn mind mappings of an agent, and a sub objective is to see to follow the facial expression strategy of the agent as a context of their interaction. A *facial expression strategy* is the behavior patterns to decide which emotion to be expressed according to each situation. For an agent, a primal objective of a mutual mind reading game is to collect instances for instance-based learning of an agent both efficiently and broadly. An instance is a pair of an estimated primitive mind (i.e. an *emotion symbol*) and a observed facial expression. In this paper, we assume that the agent follow the fixed facial expression strategy according to the game context that is natural for a human user. An example of expression strategy is that an agent expresses pleased emotion when it's guess is correct.

Procedures of a mutual mind reading game are given in the following. Note that an agent tells its correct mind to a user when his/her answer is incorrect, but a user does not do so to reduce his/her cognitive load.

1. An expression of an agent is displayed to a user through GUI.
2. A user guesses agent's mind from seeing the expression, and tells the mind to an agent by clicking a button.
3. An agent replies "Yes" (the guess is correct) or "No" (the guess is incorrect) with the correct mind as judgment against the other's guess.
4. An agent sees an expression of a user by a CCD camera.
5. An agent guesses user's mind from the captured expression, and shows the mind to a user through GUI.
6. A user replies "Yes" (the guess is correct) or "No" (the guess is incorrect) as judgment against the other's guess.
7. The above procedures are repeated until a finish condition of mutual learning is satisfied.

Then we describe a finish condition of the game. When each two players guess the partner's each primitive mind for *n* times of continuation, the game is finished. The frequency of the correct guess of *n* can be changed

according to a degree of difficulty of the game. In this paper, the parameter n is set to 2.

2.4 User Interface

Our system is implemented on VineLinux2.1, by C/C++ programming language and GTK+ for building GUI. Also Video4Linux API was employed for image capture programming. An experimental environment is shown in Fig.2.

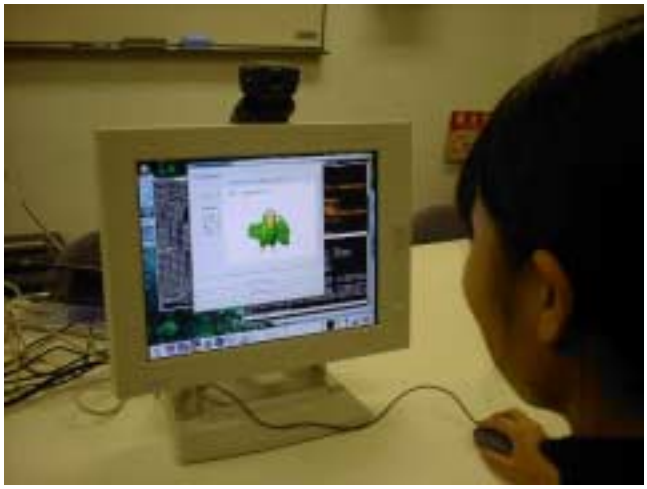

Fig.2 Environment of human-agent interaction.

Fig.3 shows a snapshot of GUI when a user guesses agent's mind. When a user clicks the "Start" button, an agent shows its expression. Then a user guesses agent's mind, and clicks one of "Primitive Mind" buttons. If a user clicks the button, an agent tells the judgment with the correct mind like a message in Fig.3. Also two progress bars are shown for indicating average success rates on the finish condition of a user and an agent. A user can understand the degrees of learning progresses by

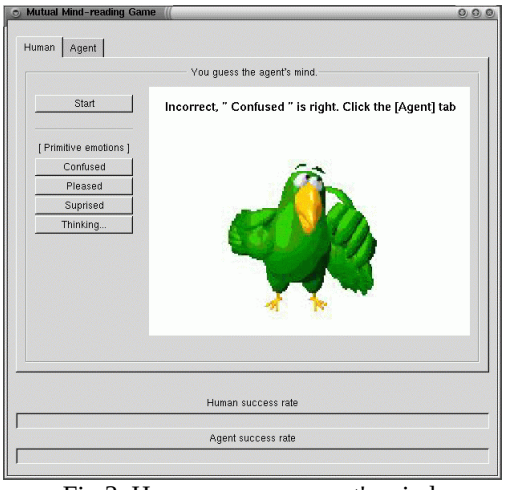

Fig.3 Human guesses agent's mind.

seeing the progress bars. A game finishes when both of two progress bars reaches to the right edges.

Fig.4 shows interface where an agent guesses user's mind. When a user clicks a "Start agent's recognition" button, an agent begins to capture user's images. After a stable expression is captured, the four images are shown in the window. Also stored instances are indicated with labels and the distance *d* between them and a captured image. Using the most similar instance, an agent guesses a user's mind and tells it to a user like Fig.4. A user answers to it by clicking `"Yes" or "No" buttons.

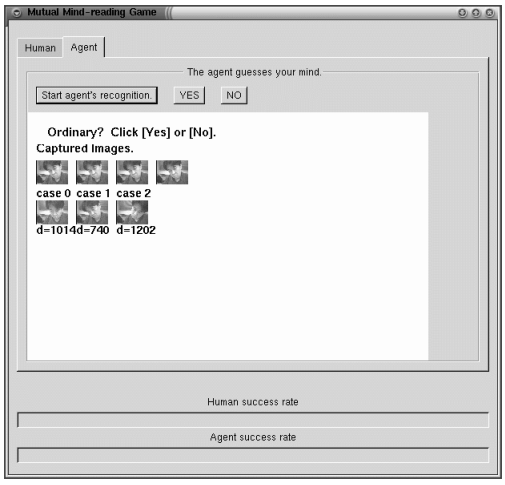

Fig.4 An agent guesses a user's mind.

3. EXPERIMENTS

To examine the conditions to occur the mutual adaptation between an agent and a user those are described in section 2.2, we made the comparative experiments. Playing the mutual mind reading game between a user and the agent, we examine two kinds of facial expression strategies of the agent, a random expression strategy (i.e., no context dependent strategy) and the game context dependent strategy. We compare the finish time of the game in that both a user and the agent acquire correct their mind mappings.

3.1 The Hypotheses

The hypotheses those we verify are following;
Comparing the agent that expresses its emotion by the game context dependent strategy with the agent by a random strategy,

1. A user's learning of its mind mapping is faster.
2. A user is easier to see or follow some regularity on the agent expression strategy.
3. A user can guess more correct emotions of the agent.

Examining these hypotheses will support that it improves a user's learning that the agent follows the game context dependent strategy.

3.2 Experimental Methods

Through all the experiments, we employed sixteen subjects of the students majoring Information Science at Nara National College of Technology. We divide these subjects into two groups as following;
Group1: Each user plays with the agent of the random expression strategy.
Group2: Each user plays with the agent of the game context dependent strategy.

We used four primitive minds and primitive expressions for an agent as shown in Fig.5 and three primitive minds "Ordinary", "Thinking", "Decline" for a user. Fig.6 shows the game context dependent strategy of the agent. This is one of the typical reactions in a process of the mind reading game. After a user guesses the agent's emotion, the agent expresses its emotion according to the context of the result of the user's guess. If the user fails to guess the agent's emotion, the agent expresses "Confused". If the user's guess is correct, the agent expresses "Pleased", and when the user succeeds to guess it again, the agent expresses "Surprised". Besides, if the user succeeds to guess it again and again, the agent expresses "Thinking". Note that each parameter in Fig. 6 is tuned so that each possibility to express an emotion becomes to be the same. On the other hand, on the random strategy, the agent expresses one of its four emotions randomly that is independent of the result of a user's guess.

After the experiments, each subject is requested to answer the questionnaire as follows;

1. Can you follow the expression strategy of the agent?
2. Do you feel that the game takes long time?
3. Do you think that the agent's guess is correct?
4. Free comments.

Fig.5 Four expressions used for experiments.

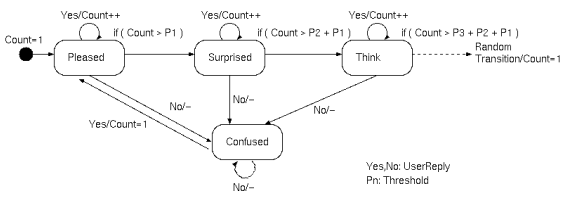

Fig.6 The game context dependent strategy of the agent.

3.3 Experimental Results

The section shows the experimental results and the results of the questionnaires. First, the averaged number of user's learning times to finish the game is compared. To compare the game context dependent strategy group (Group 2) with than the random strategy group (Group 1), Group1 takes 26 times and the Group2 takes only 19 times. Then the Group 2 plays the game shorter than Group1. Though the statistical test, the hypothesis 1 of section 3.1 is verified by p=0.1 of significant level.

Second, the hypothesis 2 of section 3.1 is verified by p=0.1 of significant level from the result of questionnaire. In Group 2, six out of eight subjects find the regularity of the agent's strategy. Note that in Group 1, two of eight subjects answered that they found the regularity of the agent's though there is no regularity.

Third, the number of failures of a user's guess is compared. In Group 1, six out of eight subjects failed to guess the agent emotion at least once. In Group 2, no one failed to guess the agent's emotion. It suggests that the hypothesis 3 of section 3.1 is verified.

Therefore, the game context dependent strategy group play the mind reading game better than the random strategy group. Note that there is no significant difference from the result of the agent learning times.

4. CONCLUSIONS

We presented a mutual adaptive interaction with context sharing between a human and a life-like agent that considers learning ability of a human user. With the mutual mind reading game, we made comparative experiments. Then we showed that the game context dependent strategy group plays the mind reading game better than the random strategy group. Our future work is to implement the agent that identifies a user's expression strategy to learn as its expression strategy.

5. REFERENCES

[1] Ms agent Web page. http://msdn.Microsoft.com/msagent/

[2] P.Maes, "Agents that reduce work and information overload", *Communications of the ACM* 37(7), pp.393-396, 1994

[3] J.Bates, "The role of emotion in believable agents", *Communications of the ACM* 37(7), pp.122-125, 1994

[4] S. Yamada, T. Yamaguchi, "Acquiring emotion mappings through the interaction between a user and a life-like agent, *9th International Conference on Human-Computer Interaction (HCI2001)*, M. Smith. et al (Eds), Usability Evaluation and Interface Design, Vol.1, pp.993-997, 2001

[5] S. Yamada, T. Yamaguchi, “Mutual Learning of Mind Reading between a Human and a Life-like Agent”, *The 5th Pacific Rim International Workshop on Multi-Agents (PRIMA-2002)*, to appear, Tokyo, Japan, August 18 - 19, 2002

[6] S.Sen, G.Weiss, "Learning in Multiagent Systems", in Multiagent Systems - A Modern Approach to Distributed Artificial Intelligence, Chapter 6, Ed. by G.Weiss, pp.259-298, 1999