Acquiring emotion mappings through the interaction between a user and a life-like agent

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Abstract

This paper describes a human-agent interaction framework in which a user and a life-like agent mutually acquire their emotion mappings through a mutual mind reading game. In these several years, a lot of studies have been done on a life-like agent like a Micro Soft agent, an interface agent, and so on. Through the development of various life-like agents, emotion has been recognized to play an important role in making them believable to a user. For making effective and natural communication between a life-like agent and a human user, they need to identify the other's emotion state from expressions and we call mappings from expressions to emotions *emotion mappings*. If an agent and a user don't obtain these emotion mappings, they can not utilize behaviors which significantly depend on the other's emotion states. We try to formalize the emotion mapping and a human-agent interaction framework in which a user and a life-like agent mutually acquire emotion mappings each other. In our framework, a user plays a mutual mind reading game with a life-like agent and they gradually learn emotion mappings each other through the game.

1 Introduction

In these several years, a lot of studies have been done on a life-like agent like a Micro Soft agent[1], an interface agent[4][5], and so on. A typical life-like agent appears on a Web shopping page and support a user in inputting his/her order and data into the page by speech recognition and synthesis. Through the development of various life-like agents, emotion has been recognized to play a very important role in making them believable to a user[2]. Emotional expressions are also effective to computer-mediated communication between humans[8]. These facts are supported by many psychologists' reports that the emotion significantly influences even rational behaviors as well as instinctive behaviors of a human[7]. Thus some researchers are trying to implement an emotion model on a life-like agent for developing a believable one to a user[2][11]. However there is a significant problem that emotion identification is difficult to both of an user and an agent.

For making the effective communication between a life-like agent and a human user, they need to be able to identify the other's emotion state through the other's expression and we call this task *emotion identification*. If the emotion identification is impossible, they are not able to act human-like behaviors which significantly depend on the other's emotion states. For example, we consider a life-like agent should kindly and carefully behave to a depressed user, and intuitively communicate its computational state to a user through a facial expression. Though emotion identification is always done among human, the emotion identification between a life-like agent and a user becomes far more difficult than between human. Because design of life-like agent's expressions significantly depends on personal preference, culture, and not all the users can understand the emotion by seeing an expression. Consequently a life-like agent and a user need to acquire relation between an expression and an emotion state when they actually encounter. We call such relation *emotion mapping*.

In this paper, we propose a human-agent interaction framework in which a user and a life-like agent mutually acquire emotion mappings each other. In our framework, a user plays a mutual mind reading game with a life-like agent and they gradually learn emotion mappings each other through the game.

First, for describing emotional interactions between a life-like agent and a human, we define an emotion state, primitive emotions, expressions, emotion transition rules and emotion mapping. Next we develop procedures of an agent to learn a user's emotion mappings. Finally, to acquire emotion mappings each other, we develop a mutual mind reading game in which a user and a life-like agent try to recognize the other's emotion state through the other's (facial) expression. They mutually answer their results on the other's emotion, and one having a correct answer gets a score. This game is designed so that a user may enjoy it, and as results, the user's cognitive load is reduced.

Velásquez proposed a emotion model which is based on Minsky's society of mind[6]. His model[11][10] is for generating human-like emotions using a multi-agent system architecture in which each agent corresponds to a primitive emotion like fear, joy and so on. Interactions among agents are defined and emotions are emerged as a result of the interactions. However the purpose of his research is to generate various emotions and moods like a human, and a framework for interaction between an agent and a user like an emotion mapping.

2 Emotion mapping

In this section , we define our framework to deal with emotional interactions between a agent and a human user. First the following primitives are introduced for describing the framework.

- *Emotion state* $S_1, \cdots, S_l$: A variable standing for a state of an agent i's emotion. The next primitive emotion is substituted for this variable.
- *Primitive emotion* $E_i = \{e_1^i, \cdots, e_m^i\}$: E_i is a set of elements of agent i's emotion. We can utilize typical elements like fear, joy and so on.
- *Primitive expression* $X_i = \{x_1^i, \cdots, x_n^i\}$: X_i is a set of primitive expressions. We deal with a single primitive expression, not a combination of plural primitive expressions.
- *Emotion mapping* $M^i_{j:x\rightarrow e} = \{x_1 \rightarrow e_s, \cdots, x_n \rightarrow e_t\}$: This means an agent(or a user) j's one-to-one mapping from a primitive expression to a primitive emotion which was learned by an agent(or a user) i. For simplicity, we assume that a single primitive expression corresponds to a single primitive emotion.
- *Expression mapping* $M^i_{i:e\rightarrow x} = \{e_1 rightarrow x_s, \cdots, e_m \rightarrow x_t\}$: An agent(or a user) i's one-to-one mapping from a primitive emotion to a primitive expression.
- *Emotion transition rule* $T^a = \{e_t^a \times \bar{e}_t^b \rightarrow e_{t+1}^a\}$: An agent(or a user) a's rule determining a transition of an emotion state from a primitive emotion e_t^a to a primitive emotion e_{t+1}^a when the a estimates the other agent(or a user) b's emotion e_t^b from its expression. The $\bar{e}$ is an estimated primitive emotion of e.

Using the above notations, we describe a framework in which a life-like agent a and a user h mutually interact through expressions as shown in Fig.1.

3 Mutual learning of emotion mappings

3.1 What should be learned?

With the framework described in Fig.1, we can define learning of emotion mappings and mutual learning of emotion mappings in the following.

Learning of emotion mappings: An agent(or a human user) acquires emotion mappings $M^a_{h:x\rightarrow e}$ (or $M^h_{a:x\rightarrow e}$) of a partner.

Mutual learning of emotion mappings: An agent and a human user mutually acquire the other's emotion mappings, $M^a_{h:x\rightarrow e}$ and $M^h_{a:x\rightarrow e}$.

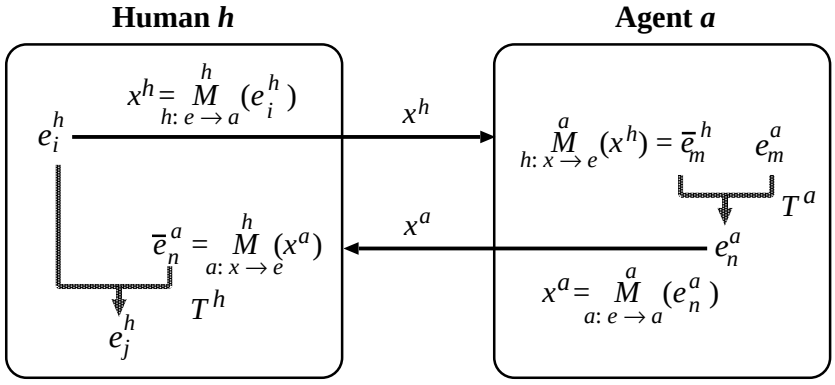

Figure 1 A framework for emotional interactions between a agent and a user.

Since a partner of a user in our framework is a life-like agent which simulates human behaviors, we can assume the following assumptions to restrict our framework for simplifying mutual learning of emotional mappings.

(A1) *Common primitive emotions*: Primitive emotions of a user and an agent are identical, thus $E = E^a = E^h$. Also

(A2) *Partially common emotion transition rules*: Emotion transition rules of a user and an agent are *partially* identical. It is just partially because the emotion transition rules are not so stable depending on situations and contexts.

3.2 Learning in an agent

Because a human user is able to autonomously learn agent's emotion mappings in our framework, we give no restriction to a user within his/her learning. Thus we develop only the learning procedures of an agent.

From an assumption (A1), an agent does not need to acquire user's primitive emotions. Furthermore the user's expressions are observed by an agent with a computer vision system using a CCD camera. Hence if a user's primitive emotion e^h is estimated by a sort of reasoning when a user's expression x^h is observed, an agent acquires an instance of an emotion mapping, $x^h \to e^h$. After an agent stores sufficient such instances through interactions with a user, it becomes able to estimate a user's primitive emotion from his/her observed primitive expression by a NN(nearest neighbor) method[3].

Thus we need to estimate a user's primitive emotion without his/her observed primitive expression. Under an assumption (A2), we utilize some rules to reason the primitive emotion like the following.

- IF much failure continues THEN a user gets distressed.
- IF a user successively wins THEN he/she feels joy.

4 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 partner's emotion state through the other's (facial) expression as the learning task of emotion mappings.

4.1 The Objective of the Mutual Mind Reading Game

The objective of the mutual mind reading game is to collect a set of instances for a NN method both efficiently and broadly for the learning of emotion mapping. An instance is a pair of a estimated primitive emotion and a observed facial expression. In this paper, a game in which a player estimates the partner's

emotion state through the facial expression to compete for the accuracy is called a *mind reading game*. "Mutual" means that both the game in which a life-like agent estimates the user's emotion state through his/her facial expression and the game in which the user estimates the agent's emotion state through its facial expression are performed in parallel. The data sampling process for an identification of the user modeling is called enrollment. The main problem of an enrollment is that the user's cognitive load becomes high. To solve this, this game is designed so that a user may enjoy it to play a part in collecting training data actively, and as results, the user's cognitive load becomes low. In general, interactions among multi-agent are classified into two types, competitive or cooperative[9]. A competitive mind reading game is to compete with each other for the accuracy in reading the emotion of an opponent between two players in the game. On the other hand, a cooperative mind reading game is to compete with other pairs for the time to finish reading the emotion of a partner accurately between two players in the game. Note that in both games, an effort to win the game must not give bad influence for sampling the training examples of natural pairs of emotion and expression.

4.2 The Overview of a Cooperative Mind Reading Game

We apply a cooperative mind reading game in which a user and an agent play cooperatively to the learning of emotion mapping.

Assumptions of the game

The primary objective of the game is the emotion identification between a life-like agent and a user. Therefore, both a life-like agent and a user play the game with fixed emotion mapping each other. Besides, users play the game with not to be stretched but to be natural facial expressions as if they behave usual expressions in their daily life.

The rules of the game

1. When a player is able to guess the partner's emotion state through the partner's facial expression, the player says the supposed primitive emotion to the partner.
2. When a player is said a primitive emotion, the player must reply whether "Yes" (the guess is right), "No" (the guess is wrong) or "Near-Miss" (the guess is wrong, but it is close to the answer) as the judgment against the partner's guess.
3. These processes are played until a finish condition of the game is satisfied.

A finish condition of the game

When each two players guess the partner's different primitive emotions 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. Note that finally, it is equal to the number of primitive emotions treated in the emotion model.

4.3 Discussions

First, we discuss the assumption of our mind reading game. There are two reasons why fixed emotion mapping is assumed during the game. First reason is that fixed emotion mapping which is equal to that of daily use generates natural facial expressions. Second reason is that fixed emotion mapping makes the learning of opponent mapping easier. Next, we argue about the intention that we used a game for emotion mapping identification. It is not easy for a human to hold various natural emotions in a short time while collecting training examples of facial expressions. For this, the learning of emotion mapping based on the mutual mind reading game is continued until the end condition of the game is satisfied. During the game, various kinds of user's emotions that arise from the result of the guess cause his/her natural facial expression. Finally, we describe convergence conditions of the mutual learning of emotion mapping. The necessary conditions of the mutual learning are the following;

1. Each learning of the opponent emotion mapping is converged.
2. $M^h_{a:x\to e}$ which a user learned becomes equal to an inverse mapping of $M^a_{a:e\to x}$ of an agent
3. $M^a_{h:x\to e}$ which the agent learned becomes equal to an inverse mapping of $M^h_{h:e\to x}$ of the user.

$$\underset{a:x\to e}{\overset{h}{M}} = \left(\underset{a:e\to x}{\overset{a}{M}}\right)^{-1} \qquad \underset{h:x\to e}{\overset{a}{M}} = \left(\underset{h:e\to x}{\overset{h}{M}}\right)^{-1}$$

5 Conclusion

This paper describes a human-agent interaction framework in which a user and a life-like agent mutually acquire their emotion mappings through a mutual mind reading game. For describing emotional interactions between a life-like agent and a human user, we defined emotion states, primitive emotions, expressions, emotion transition rules and emotion/expression mappings. Then, to acquire the emotion mapping each other, we developed a mutual mind reading game in which a user and a life-like agent try to recognize the other's emotion state through the other's expression.

Unfortunately the descriptions are conceptual. Thus our system should be fully implemented and we need to verify the feasibility of our framework through various experiments with subjects. We are currently developing a whole framework in which a life-like agent and a human user naturally interact each other.

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