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Interactive Agents with Artificial Mind

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***Abstract*—** This paper discusses an artificial mind model and its applications. The mind model is based on some theories which assert that emotion is an important function in human decision making. An artificial mind model with emotion is built, and the model is applied to action selection of autonomous agents. In three examples, the agents interact with humans and their environments. The examples show the proposed model effectively work in both virtual agents and real robots.

***Keywords*—**Artificial mind, emotion, interactive agent, pet robot

I. Introduction

AN artificial mind model for autonomous agents is proposed. We have been studying on human mind and communication processes, and built the mind and consciousness model (MaC model) as a first result. The concept of the model is based on multi-disciplinary theories as follows.

Recent studies in brain science, cognitive science, and psychology show that emotion is an important function in human decision making [1]-[3]. Scientists in the field of artificial intelligence also argue that machines should have emotion to solve problems [4][5]. Dennett proposed the multiple draft theory that explains human consciousness as interaction among multiple distributed processes [6]. Sloman asserts that human mind consists of at least three layers [7]. They are reactive, deliberative, and self-consciousness levels.

The implementation architecture enables agents to have autonomy and communication abilities by realizing the concept as computational algorithm. It is important for the agents to have these abilities. The autonomy enables the agents to make a decision, a plan, and execute actions independently without detailed instructions from their users. The communication enables them to share knowledge with their users and other agents in order to achieve tasks cooperatively. These abilities should be realized by artificial minds.

We especially focus on how to express emotions and personalities in this paper, because information processing with emotions is not only imporotant but also useful for many applications such as electronic secretaries, tutoring systems, and autonomous characters in entertainment [8][9]. For instance, children tend to be under the impression that characters in Disney animation have minds. A reason for this phenomenon is that characters express rich emotions and personalities. Character's behaviors with emotions and personalities facilitate anthropomorphic view [10]. Reeves and Nass state that modern media engage old brains which are not evolved to twenty-century technology. There is no switch in the brain that can be thrown to distinguish the real and mediated worlds [11]. There are some of the reasons why people personify behavior of a machine and have illusions that cartoon characters have human-like mind. Artificial agents with emotions gives such illusions to the users by utilizing these human characters.

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This paper shows three examples of agents. They are applications in the entertainment fields, but in the future we expect to improve the model and it will make applications in the fields such as information processing assistance and daily care.

II. Mind and Consciousness Model

A. Conceptual model

We propose a conceptual model of mind and consciousness based on those theories. Figure 1 illustrates the model. There are two major mechanisms in the model. The first one uses emotion for decision making without time-consuming reasoning. It consists of the cognitive and emotional processes, and they interact with each other. The emotional process generates emotions according to the cognitive appraisal theory [12]. The other mechanism works for allocating limited computational resources in two methods. One is separating reflective and deliberative processes. The reflection doesn't require deep knowledge processing, while the deliberation does. The other method is selective attention for external stimuli and internal states. The resources are allocated to processing objects which have relation to goal achievement.

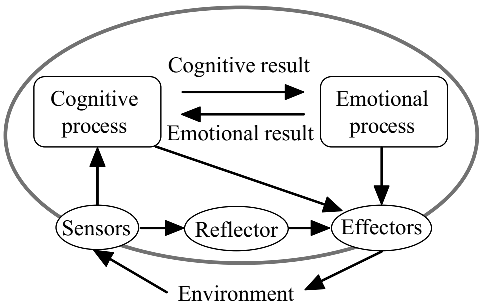

Figure 1. Conceptual model of mind and consciousness

B. Implementation architecture

Figure 2 illustrates the implementation architecture of the MaC model. Agents are able to select actions, learn the environment, and form personalities by using the model as follows.

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The agent interacts with environments through Sensors and Effectors. The Sensors detect stimuli from the environment, and extract physical features such as sound's and tactile intensities. The extracted features are transmitted to the Reflector and the deliberative action selection process. The Effectors generate outputs according to action commands from the Reflector or the deliberative action selection process. For example, the effectors are actuators in the case of a real world's agent, while computer graphic animation is drawn in the case of a cyber agent.

There are two types of action selection in the model. Reflective action selection is used to generate urgent action such as following a movement of an object. In order to generating such an action, the Reflector has direct mapping rules from the features to action commands. When the Reflector receives inputs from the Sensors, it outputs corresponding action commands to the Effectors.

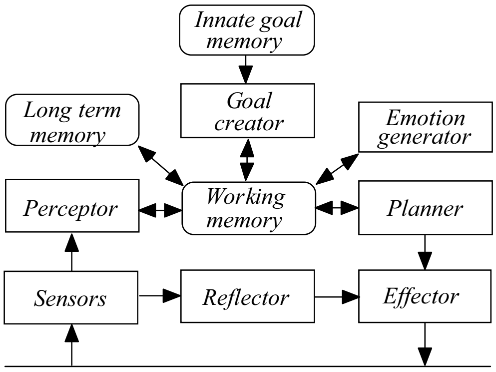

Figure 2. Architecture of the MaC model

Deliberative action selection is more complex system. It uses three memory modules (Innate goal memory, Working memory, and Long term memory) and four processing modules (Perceptor, Emotion generator, Goal creator, and Planner).

The Innate goal memory has some innate goals. The goals are the highest rank goals that are given by the designers or users. Each innate goal has intensity that changes as a function of time passing and stimuli. Every processing module in the deliberative process shares information in the Working memory.

The Long term memory (LTM) stores knowledge that is captured via interactions with environment. The knowledge is used to adapt the agent's behavior to the users and environment. It consists of contribution degree, preference degree, user information, and episodic memory.

The Perceptor interprets features from the Sensors in light of prior actions, and evaluates the change of state with respect to the agent's goals. For example, the interpretation includes recognition of tactile sensation, speech, and image such as human faces. When several stimuli are received from the environment, the Perceptor select the most important stimuli with respect to the goals by using a selective attention process. The process uses the intensities of stimuli, and knowledge stored in the Long term memory.

The Emotion generator generates emotions, moods, and preferences as internal states of an agent. The MaC model uses these states for two purposes. The first is conflict resolution in decision making. The second is to indicate the agent's internal states and to facilitate anthropomorphic view by expressing them externally. Emotions are labeled such as happiness and sadness. Each emotion has its intensity. The change of the intensity is based on cognitive appraisal theory. For example, the intensity of happiness is increased if an important goal successfully achieved, while that of sadness is increased if the goal fails. The intensity decreases according to time passing if any stimuli aren't received. Moods are long term states in comparison with emotions, because the decreasing ratio of moods is smaller than that of emotions. The continuity of the moods enables agents to generate emotions context dependently. For instance, a good mood increases the intensity of happiness, while a bad mood increases the intensity of sadness. Preferences are represented by the preference degree values. A value of an object increases if the object makes the agent happy, while the value decreases if the object makes the agent angry or sad. Preferences are also used to control emotions depending on contexts. For example, a liked object increases the intensity of happiness, while a disliked object increases the intensity of anger.

The Goal creator creates empirical goals that are concrete/sub goals to achieve the innate goals. The empirical goals are created according to the situation and experience in the interaction with the environment. The agents learn causal relations between stimuli and the innate goals, and create the empirical goals by referring the captured knowledge such as contribution degrees. The knowledge is stored in the Long term memory. Each empirical goal has an importance degree, and it is computed by using not only the knowledge but also emotions. A goal with the highest importance degree is selected from candidates. Thus, when there are several goals for a given situation, emotion is used to resolve a conflict between actions for achieving the goals.

The Planner has action selection rules and selects a proper action in order to achieve a goal. The action selection depends on situations. For example, when an agent's goal is to get an object and there isn't it, then the next action is to seek it. If the agent find it, then next action is to approach it. Emotions also influence the action selection. If there is another agent near the object, and feels fear for the agent, then the next action is to run away.

C. Emotion Generation

The Emotion generator generates emotions using contents of the working memory and the LTM. Figure 3 shows this process. It is divided in two steps. In the first step, cognitive appraisals (i.e. desirability, praiseworthiness, and appealingness) are computed. For example, happiness is generated if an important goal succeeds, while sadness emerges if the goal fails. An agent gets angry if another agent is responsible for the goal failing. In other words,

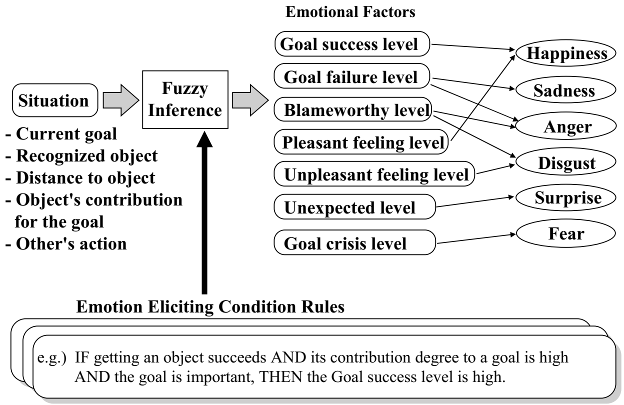

Figure 3. Framework for emotion generation.

the cognitive appraisals are regarded as emotional factors. Emotional intensities depend on the levels of the emotional factors. The levels of the emotional factors are obtained using the emotion eliciting condition rules, which are implemented by means of fuzzy inference rules. Our model uses seven emotional factors. Examples of the emotion eliciting condition rules are as follows;

- *Goal success level (GSL)*: IF getting an object succeeds AND its contribution degree to a goal is high AND the goal's importance is high, THEN the *GSL* is high.
- *Goal failure level (GFL)*: IF getting an object fails AND its contribution degree to a goal is high AND the goal's importance is high, THEN the *GFL* is high.
- *Blameworthy level (BWL)*: IF getting an object is prevented by another agent AND its contribution degree to a goal is high AND the goal's importance is high, THEN the *BWL* is high.
- *Pleasant feeling level (PFL)*: IF a good tactile stimulus is sensed AND its desire level is high AND its intensity is high, THEN *PFL* is high.
- *Unpleasant feeling level (UFL)*: IF a bad tactile stimulus is sensed AND its intensity is high, THEN *UFL* is high.
- *Unexpected level (UEL)*: IF a new or unexpected stimulus is sensed AND its intensity is high, THEN *UEL* is high.
- *Goal crisis level (GCL)*: IF a goal is threatened by another AND the goal's importance is high, THEN *GCL* is high.

The second step of the Emotion-generator is to compute emotion intensities. There are many kinds of emotion theories in the fields of psychology, physiology, and cognitive science. James denied the existence of explicit emotional components in our minds and argued that an emotion is the feeling of what is going on inside our body [13]. This idea that emotions arise as sensations in the body has become known as the peripheral theory. Cannon had argued against the peripheral theory and proposed that bodily changes are produced by the brain [14]. Other theorists proposed explicit components for emotion types [15][16]. We employ the following emotion types because they are easy to explain and understand; *happiness*, *sadness, anger*, *disgust*, *surprise*, and *fear*. Emotion intensities are obtained by using emotional factors, time decay, and other emotions. Emotional factors influence the intensities by using production rules as follows;

- IF the *GSL* is higher than its threshold, THEN increase the Happiness intensity in proportion to it.
- IF the *GFL* is higher than its threshold, THEN increase the Sadness intensity in proportion to it.
- IF the *GFL* is higher than its threshold and the *BWL* is higher than its threshold, THEN increase the Anger intensity in proportion to their product.
- IF the *BWL* is higher than its threshold, THEN increase the Disgust intensity in proportion to it.
- IF the *PFL* is higher than its threshold, THEN increase the Happiness intensity in proportion to it.
- IF the *UFL* is higher than its threshold, THEN increase the Disgust intensity in proportion to it.

The emotion intensity is calculated using equation (1).

$$E_i(t) = \frac{1}{1+\exp\{(-X(t)+0.5)/0.1\}} \qquad (1)$$

$$X(t) = X(t-1) + \delta - \gamma + \sum_j W_{ji} E_j(t-1)$$

where E_i is the intensity for Emotion i at time step t; δ is the input from the rule set described above; γ is a decay coefficient, and W_{ji} is excitatory or inhibitory gain from Emotion j to Emotion i. The nonlinear function constraints the intensity between 0 and its saturation value. There is a threshold for each Emotion. If E_i is higher than both the threshold and other emotion intensities, then Emotion i become active.

D. Learning

It is difficult for developers to code pre-defined programs that enable agents to cope with all situations. In this respect, the agents are expected to learn the values of stimuli and actions. The MaC model captures three types of knowledge (contribution degrees, user information, and episodic memory) as follows.

Contribution degree values are obtained in the Perceptor. It evaluates relations between objects and goals, and calculates the object's values for the goals. For example, if an agent achieves a goal with an object, the object's value for the goal becomes higher. On the other hand, if an object entangles a goal, the object's value for the goal becomes lower. As the result, a positive value means that the object contributes for a goal achievement, while a negative value means that the object causes a goal entanglement.

The user information is captured via interaction with users. For example, the Perceptor connect a user's face with her/his attributes such as favorite music.

The episodic memory represents history of relation between the agent's action and the effect. If a series of actions causes a goal achievement, then the memory of the action series is useful when the agent wants to achieve the same goal next time. If an action causes a goal entanglement, then the agent doesn't select the action when it wants to achieve the same goal.

E. Personality information

People are able to explain and guess the other's behavior by evaluating his/her personality [10]. In the same way, it is important for an agent to form its personality, which assists users to guess its role and behavior. The model can make agents to form a variety of personalities by changing parameters in the following modules.

The Innate goal memory has a time constant and a threshold for each innate goal's intensity.

The Goal creator has coefficients for calculating goal importance degree values.

The Perceptor has coefficients for calculating contribution degree values.

The Emotion generator has increasing and decreasing ratios for each emotion, mood, and preference.

The Effector has thresholds for emotion intensities. When the intensity of an emotion exceeds the threshold, then the emotion is expressed externally.

III. APPLICATIONS

A. Virtual world's creatures

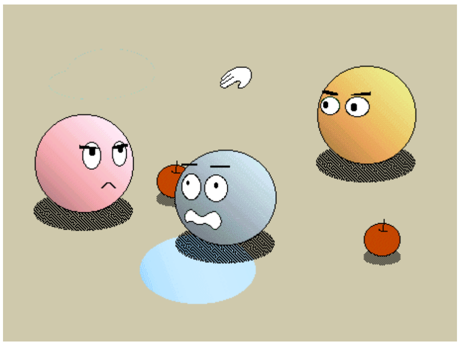

Figure 4. Screenshot of virtual world's creatures

Virtual world's creatures are cyber agents. Figure 4 illustrates an screenshot of the virtual world. The creatures interact with each other, and also with users via a tactile sensor. The sensor is connected with the computer, and tactile signal is transmitted to the creatures.

As a reflective action, a creature reacts when a user touches it via the tactile sensor. For example, a creature blinks its eyes when a user beats it.

In deliberative action selection, the creatures have five innate goals: "satisfy hunger", "satisfy thirsty", "sleep", "get good feeling", and "avoid bad feeling." Good and bad feelings are being petted and beaten respectively. The Goal creator creates empirical goals for these innate goals by using captured knowledge. After an empirical goal is selected, the Planner selects a suitable action from about 20 actions in order to achieve the goal. Emotions influence the goal and action selections. Each creature generates six kinds of emotions (happiness, sadness, anger, disgust, fear, and surprise) according to situations. For example, when a creature is hungry and other creature gets a food, the creature gets angry and threatens the other. The emotions are represented by facial and vocal expressions.

In learning, each creature obtains contribution degrees of objects in the world. For example, user can feed virtual apples to the creatures. Apple's contribution degree for the goal of satisfying hunger becomes higher, because the goal is achieved by eating it.

The creatures also use the episodic memory. They select suitable actions based on success and failure experiences. For example, suppose that a creature is approaching an apple and threatened by another. The creature feels fear by the threat, and this episode is memorized. Because of the memory, the creature won't approach an apple when the other is near it.

Each creature has its personality, and different trend of action and emotional expression. For example, high increasing ratio of "anger" makes an agent aggressive, while low ratio makes it gentle.

B. Pet robot

Figure 5 shows a cat type pet robot. It has tactile, auditory, and postures sensors to understand the human action and surroundings.

The robot has three types of reactive action. If she senses loud noise, she turns her face toward the direction of it. She blinks her eyes and wags her tail when she senses noise or tactile stimuli.

Deliberative action selection is based on innate goals and emotions. We investigated behaviors of real cats and mapped them to the MaC model's emotions. The goals are "sleep", "get good feelings", and "avoid bad feelings." For example, when the intensity value of getting good feeling become bigger than that of other goals, then the Goal creator selects an empirical goal "be petted", and the Planner selects "beckon" as an action. If the user pets the robot, the goal is achieved and the intensity of emotion "happiness" is increased. This increase of the intensity means that the robot feels relieved. Because of the relief, the Goal creator selects a goal "sleep", and the Planner selects an action "lie down." The robot expresses actions in eight dimensions of freedom.

Figure 5. Pet robot

In learning, the robot changes trend of behavior according to the interaction with users. For example, suppose that frequency of tactile stimuli changes the parameters of goal and emotion. If the user pets it frequently, then it becomes gentle. On the other hand, if the user beats it frequently, then it becomes aggressive.

C. *Interface agent "Stellar"*

Stellar is a cyber agent. She is able to interact with users by means of spoken language and face recognition.

As a reflective action, Stellar reacts to sound and faces. She looks at a user's face at the interaction. Her eyes follow movement of a user's face. When she hears big noise, she turn her face to the direction of it.

In the deliberative action selection, Stellar has several goals of speech conversation. One of the goals is to play a piece of music, which is selected from a user's favorite genre such as rock, pop, and classic. Stellar has some sub goals as empirical goals in order to achieve the goal. The sub goals are "know whether a user likes music or not", "know the user's favorite music genre if she/he likes music", "know whether the user wants Stellar to play a piece of music."

The MaC model controls the dialogue to get the information from the user. Emotions are used for value judgment in the dialogue control. For example, if a user's answer is that she/he dislikes music, Stellar become sad and ask the question again in order to achieve the goal. Emotions are shown to users by facial expressions in order to inform them of Stellar's internal states. Figure 6 shows three examples of Stellar's facial expressions.

The agent also has a learning ability. From a social point of view, agents should use information obtained from the users in their conversation. Stellar memorizes the information in the Long term memory. The information of a user is connected with her/his face image. When the user comes again before Stellar, the Perceptor recognizes the user's face via a CCD camera, and recalls the user's information from the memory. The recalled information is used in dialogue. This function prevents Stellar from asking same questions repeatedly.

In order to build Stellar's personality, we designed her as a cheerful teen girl. Parameters in the Emotion generator are tuned to this design. Stellar also has innate goals that represent her preferences. One of them is that Stellar wants users to like pop music. If a user answers that she/he likes music, then Stellar becomes happy and expresses the emotion. The user looks at Stellar's happy face and guesses that Stellar also likes pop music.

Figure 6. Examples of Stellar's facial expressions

IV. Experiments

We conducted three experiments in the virtual world's characters shown in Figure 4. The aim of the experiments is to evaluate the emotion model and the characters for their life-like behaviors. In the first experiment, the intended emotions displayed by the model were compared with the users' observations on the characters' expressional states. TABLE I shows some example of relations between character's emotions and situations. In the second experiment, the users after interacting with the characters in virtual world, reported their impression about the characters. In the third experiment, the users evaluated the characters' emotions and personalities in eight dimensions. Twenty-three users (13 males and 10 females) participated in each experiments. Prior to the experiments, the participants were only given the information about the virtual world as the following: (1) There are three characters in the world and they behave autonomously. (2) The characters drink water at the puddle if thirsty and eat an apple that the user puts in the environment if hungry. (3) The user can pet or beat the characters with the simulated hand. (4) The characters express their emotions depending on the situation. (5) Emotions are displayed via facial or vocal expressions. The users, however, were not told of the emotions, motivations, personalities assigned to each character. TABLE II shows the setting scheme for each parameter. For instance, "B<Y" means that a parameter of Blue is set to a smaller value than that of Yellow.

TABLE I
Emotions and Their Situation Examples

Emotion	Example of Situation
Happiness	- An agent is petted by a user - An agent eats food when she is hungry
Anger	- Another agent steals food
Sadness	- A user's hand goes away when an agent wants to be petted
Fear	- Another agent threatens of attacks
Disgust	- Disliked object approaches
Surprise	- A loud noise is heard suddenly

TABLE II
Personality Parameters Setting

Factor	Parameter Setting (B: Blue, Y: Yellow, P: Pink)
Innate goal	- Desire level for good tactile stimuli: P < Y < B
Empirical goal	- Decreasing ratio of holding degree: P << B, Y
Emotion threshold	- Happiness: B < Y < P - Anger: P < Y < B - Sadness: B < Y < P - Fear: B < Y < P - Disgust: P < Y < B - Surprise: B < P < Y
Action threshold	- Threat: P < Y < B - Request to give good tactile stimuli: B < Y < P - Request to give an object: B < Y < P

A. Experiment 1: Comparison between expressed emotion and user estimation

The procedure for the experiment is as follows: The participant verbally described their observations about each character's emotional states as they viewed a six-minute video segment of the virtual world. The user's protocol was recorded. A total of 522 reports were collected. The protocol data were analyzed and classified into six emotional states. The observed emotions were compared to the intended emotions displayed by the characters. TABLE III shows the results of the comparison analysis. The ratio was obtained using Equation (2).

$$Ratio = \frac{Number\_of\_matched\_emotions}{Number\_of\_user\_utterances} \quad (2)$$

The results in general showed high matching rates between the observed emotions and the intended emotions. *Happiness* and *Anger* showed an especially high matching rate. One reason for that is that their expressions and situation is easy to understand. *Surprise* had the lowest matching rate. Most of the misinterpretations were confusions with *Fear*. This can be explained by similarity of the situations in which these emotions are displayed. If one character is yelled at by another, which tries to receive attention, it feels *Fear*. On the Other hand, if one character suddenly hears a loud noise while paying attention to something else, it displays *Surprise* at the noise. In addition, the facial expressions for these emotions are also similar. *Disgust* had the second lowest rate and was often misinterpreted as *Anger* or *Pain*. Thus, these results suggest that the users based their interpretations of the character's emotions on the situations in which they were displayed. This implies that the design of the emotion mechanisms should integrate the context.

TABLE III
THE RESULT OF COMPARISON BETWEEN
THE EXPRESSED EMOTIONS AND THE USER ESTIMATION

	Happ.	Anger	Sad.	Fear	Disgust	Surprise	Total
Ratio(%)	100	100	80.2	89.0	67.9	63.8	87.7

B. Experiment 2: Enumerating emotions, motivations, and personalities

In this experiment, the users were asked to actually interact with them in the virtual world on the computer. They could, for example, feed and touch the characters with a mouse and a stuffed puppet connected to the virtual world. After a fiveminute interactive session, the user was asked to write down their impressions about the character's emotions, motivations, and personalities.

The emotions elicited by the participants were as follows: *Happiness* (19), *Anger* (19), *Fear* (16), *Sadness* (15), *Surprise* (4), *Disgust* (3), *Perplexity* (4), *Sulk* (3), *Threat* (3), *Lonesome* (2), and *Regret* (2). The following have one answer; *Liking*, *Discouragement, Expectation*, *Uneasiness*, *Curiosity*, *Hunger*, *Desire*, *Trouble*, *Spoilt*, *Perverseness, Pain*, *Displeasure*, *Caution*, *Satisfaction*, and *Tickle*. Here, each parenthesized number represents the number of users and the total number of the users are 23. These results suggest that *Happiness*, *Anger*, *Fear*, and *Sadness* gave strong impressions to the users. An interesting point to note is that the users drew more variety of emotions from the character's behaviors than the six emotional states that each character displayed. Context seems to play a significant role for this phenomenon. It is feasible to assume that the user interprets a character's emotion by taking into consideration the context of the virtual world.

Motivations pointed out were as follows: *Appetite* (18), *Thirst* (10), *Monopoly* (8), *Playing with a user* (5), *Feeling good tactile stimuli* (6), *Avoiding bad tactile stimuli* (3), *Defending territory* (2), *Communication* (2), and *Fight* (1). This results shows that instinctive motivations were easy to understand for many users. But some users could find social motivations such as *Monopoly*, *Defending territory*, and *Communication*. Not a few users pointed out *Monopoly* because the decreasing ratio of Pink's holding degree was very small as shown in TABLE II. This result shows an effect of the personality parameter.

Personalities pointed out by the users were shown in TABLE IV. The result shows that there is correlation with the parameters in TABLE II. In particular, Pink's personality seemed obvious to the users. Many of them indicated that the character was *Irritable*. The thresholds for *Anger* and *Threat* are considered to have caused this result. Likewise, the threshold for Threat can be attributed to *Offensiveness*. *Egoism* can be explained using the decreasing ratio of the holding degree. Pink, for example, tended to occupy the puddle because of the parameter. Blue gave the impression of *Timidness* because the thresholds for *Sadness*, *Fear* and *Surprise* are lower than those for the other characters. The threshold for *Anger* and *Threat* seem to affect *Gentleness* of Blue. It is supposed that *Spoilt*, *Sociable*, and *Curious* of the character were caused by the lowest threshold of two requests in TABLE II. *Lonesomeness* may be caused by the lowest threshold of *Sadness*. Yellow was seemed to be *Normal* because most parameters of that character were set to be middle among the characters. Thus, these result shows that parameter control is effective to express the character personalities.

TABLE IV
PERSONALITIES POINTED OUT BY USERS

Character	Pointed Personalities	Number of Users
Blue	Timid	7
	Obedient	3
	Gentle	2
	Spoilt	2
	Sociable	2
	Curious	1
	Lonesome	1
Yellow	Normal	5
	Own pace	3
	Timid	3
Pink	Irritable	15
	Offensive	3
	Egoistic	3
	Unkind	2

TABLE V
GENERAL IMPRESSIONS OF THE CHARACTERS.
EACH FIGURE REPRESENTS THE NUMBER OF USERS.

	YES			Neither	NO		
	absolutely	almost	slightly		slightly	almost	absolutely
Life-like behavior	1	8	6	4	2	2	0
Autonomous behavior	2	10	1	4	5	1	0
Motivated behavior	1	11	9	0	0	2	0
Learning ability	0	7	3	9	2	2	0
Emotional behavior	2	11	9	0	0	1	0
Personality	9	12	2	0	0	0	0
Interaction with users	2	4	10	4	3	0	0
Interaction with others	4	15	4	0	0	0	0

C. *Experiment 3: General impressions*

In this experiment, the users were given a questionnaire, which asked them to evaluate the characters' behaviors in eight dimensions. The users answered to each dimension using seven levels of responses. The results were summarized in TABLE V. Each number in this table represents the number of users. These result shows that about 65 % of the users agreed with the life-likeness of the behavior. Especially, motivated and emotional behavior gave remarkable impressions. Personalities were also effective. But the impression of learning ability is relatively weak. This is one of problems to be solved.

V. SUMMARY AND FUTURE WORKS

This paper presented the mind and consciousness model for artificial agents. The mind mechanism uses emotion in order to resolve conflicts among several actions. The consciousness mechanism executes reactive and deliberative processes, and selective attention in order to allocate limited resources appropriately. The model has been applied to three types of agents, which are two cyber agents and a real robot. Evaluation results showed that the proposed method is effective to give users the illusion of life.

Future works will include improving learning mechanism of the model, and evaluating emotions and personalities of agents by user impressions. Functions of processing long term contexts are required to smoothly communicate with users. The history of interaction will be memorized to generate more intelligent behavior by means of the functions.

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