Emotion Model for Life-like Agent and Its Evaluation

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Abstract

This paper proposes an emotion model for life-like agents with emotions and motivations. This model consists of reactive and deliberative mechanisms. The former generates low-level instantaneous responses to external stimuli that come from the real world and virtual worlds. The latter mechanism especially focuses on emotions. A basic idea of the model comes from a psychological theory, called the cognitive appraisal theory. In the model, cognitive and emotional processes interact with each other based on the theory. A multi-module architecture is employed in order to carry out the interactions. The model also has a learning mechanism to diversify behavioral patterns. These features are effective in giving users the illusion of life. We applied the proposed model to characters in a virtual world and show the results obtained from three experiments with users.

Introduction

A goal of the present study is to develop life-like agents which can effectively communicate with humans. People communicate with each other by simulating their partner's mental processes in their mind. This paper argues that an agent communicating with people should have an ability to simulate their mental processes, and proposes an agent with an artificial mind.

What are important features for such artificial minds?

One important feature of the artificial minds is the ability to understand emotions because people communicate with each other via expressing and estimating emotions. William James emphasizes that emotion is the predominant operation, mediating both cognition and action (James 1980). Minsky argues that emotion influences goal constructing in problem solving and that AI should have the ability of processing emotion (Stork 1997). Therefore, a machine should be able to process information about a user's emotions so that it can understand the user's goals as well as other information. To achieve this, it is crucial to build computational models of emotion.

Another important feature of the artificial mind is the ability to understand motivation. Dreyfus says that people interpret the meaning of matters according to their desires and concerns (Dreyfus 1978). People consider others' motivation when they estimate their emotion and intention, explain their action, predict their future action. Therefore, it is necessary for user interface agents to understand user's motivation. Conversely, it will be easy for users to predict agent's behavior which is based on its motivation. Dennett's intentional stance is the strategy of interpreting behavior of an entity (person, animal, artifact, whatever) by treating it as if it were a rational agent that governs its action selection by a consideration of its beliefs and desires (Dennett 1996). Behavior of an intentional system is predictable and explainable if people attribute beliefs and desires to it.

Thirdly, agents should be adaptable to their environment and users' preferences. Agents that lack these abilities have limitations of satisfying their users. An electronic secretary repeats the same error if she cannot learn.

Fourthly, resources for computation, such as the number of processors and the capacity of working memory, are limited. Selective attention is required for the agent to process the most important matter in a given situation.

Finally, not all behaviors are generated under deliberative mechanisms in the case of real life. For instance, reactive mechanisms are required to avoid a sudden obstacle. Brooks has proposed an architecture for such reactive behaviors (Brooks 1986). An agent should have both reactive and deliberate behaviors. Therefore, the integration of the behavior-based AI (i.e. bottom-up approach) and the symbolic-based AI (i.e. top-down approach) is crucial in life-like behavior.

This paper proposes a mind model for life-like agents which have the features described above: i.e., 1) expressing emotion, 2) generating behavior based on motivation, 3) learning, 4) selective attention, and 5) generating reactive behavior. We especially focus on how to express emotions and personalities in this paper because information processing with emotions is not only important but also useful for many applications such as electronic secretaries, tutoring systems, and autonomous characters in entertainment (Maes 1995; Picard 1995). For instance, children tend to be under the impression that characters in Disney animation have minds. A reason for this phenomenon is that the characters express rich emotions and personalities. Character's behaviors with emotions and personalities facilitate anthropomorphic view (Hayes-Roth 1997). 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 (Reeves and Nass 1996). These 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 give such illusions to the users by utilizing these human characteristics.

Implementation issues concerning the present model are as follows. Firstly, the model uses a multi-module architecture to realize emergence of behaviors by interactions between cognitive and emotional processes. Secondly, fuzzy inference is applied to realize flexibility in the behavior. Thirdly, the agent can learn causal relations between stimuli and their goals. This learning mechanism diversifies the behavior. Finally, a set of tactile sensors to detect stimuli from the real world is integrated with reactive behavior.

The remainder of the paper is organized as follows. Next section presents our model. In the third section, the model is applied to cartoon characters in a virtual world. The fourth section shows the results of evaluations from the point of life-like behavior. The fifth section discusses some related work. The final section describes summary and future work.

Emotion Model

Figure 1 illustrates our conceptual model. It consists of reactive and deliberative mechanisms. The former mechanism covers direct mapping from sensors to effectors. We employ the terms, "sensors" and "effectors", in both the real and virtual worlds. The deliberative mechanism has two processes: the cognitive and emotional processes. The cognitive process executes recognition, decision-making, and planning. The emotional process generates emotions according to the cognitive appraisals which are described in the next paragraph.

The deliberative mechanism is based on the cognitive-based emotion model of the cognitive appraisal theory (Ortony, Collins, and Clore 1988). In the theory, a person's appraisal of an emotion-inducing situation consists of three central variables: *desirability*, *praiseworthiness*, and *appealingness*. These variables are applied to event-based emotions, agent-based emotions, and object-based emotions, respectively. Desirability is evaluated in terms of a complex structure, where there is a focal goal that governs the interpretation of any event. The desirability of the event is appraised in terms of how it facilitates or interferes with this focal goal and the sub-goals that support it. Similarly, the praiseworthiness of the agent's actions is evaluated with respect to a hierarchy of standards, and the appealingness of an object is evaluated with respect to a person's attitudes. Emotions, which are generated according to the cognitive appraisals, influence cognitive processes such as sub-goal constructing and conflict dissolving in problem solving (Minsky 1986; Stork 1997). Damasio argues that emotions are necessary for problem solving because when we plan our lives, rather than examining every opinion, some possibilities are emotionally blocked off (Damasio 1994). Thus, the cognitive and the emotional processes interact with each other.

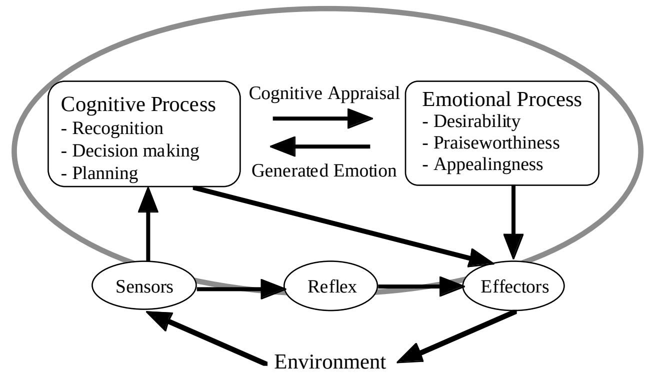

Figure 1: A Conceptual model of the cognitive appraisal theory.

Model Configuration

This section describes the model configuration. Minsky has presented an idea that a mind consists of many small components called agencies. Each component has a very simple function but the interaction among them lead to complex behaviors (Minsky 1986). We adopt this idea for developing our model. The configuration of our model is illustrated in Figure 2. Each rectangle with squared corners represents a functional module, while each rectangle with rounded corners represents a memory module. The modules in our model are executed in parallel. It has no central commander which directly influences all modules. Each module interacts with its neighbors. This local interaction in a multi-module architecture lead to emergence of complex behaviors. The memories and functional modules are described as follows;

There are three kinds of memory components in the model: Innate goals, Empirical goals, and Long Term Memory (LTM). The Innate goals are built-in goals. The Empirical goals are generated depending on the situation and experiences. The LTM keeps captured knowledge to be used for recognizing outer stimuli and generating the empirical goals.

Innate Goals. The Innate goals are built-in goals and assumed to correspond to the instinct of self-preservation in animals. Some examples are thirst, hunger, sleepiness, defense. There is a desire level for each goal. The levels of thirst, hunger, and sleepiness increase according to time series and decrease when the goals are satisfied.

Empirical Goals. The Empirical goals are concrete goals for the innate desires described above and are generated in the Goal-creator. The goal creation depends on the situation and experiences in interactions with the environment. The agents learn causal relations between stimuli and the innate goals. For example, they empirically find objects which contribute to satisfying hunger, and stores the knowledge in the LTM. Learning is executed in the Perceptor described below.

Long Term Memory (LTM). The LTM stores knowledge which is captured via interactions with the environment. Continual changes in the empirical knowledge diversify behavioral patterns. The knowledge includes the following

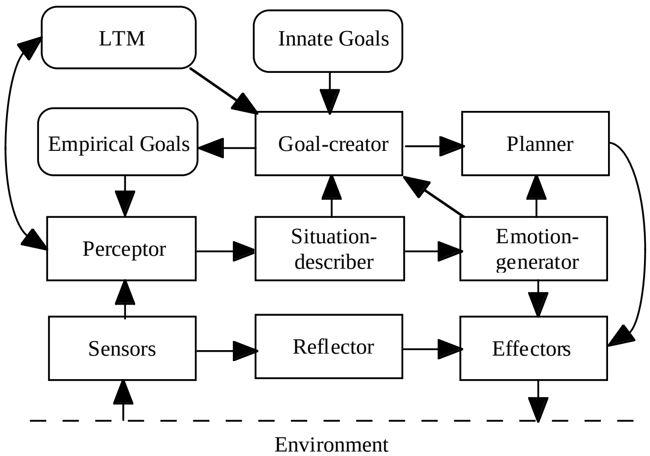

Figure 2: Configuration of the emotion model.

variables for each object:

- *Attribute values* are physical features of objects (e.g. colors, shapes, etc.). They are used to recognize objects and stimuli.
- *Novelty value* is set to the highest value at first and decreases according to the number of contact times.
- *Contribution degree value* represents how much an object contributes to each innate goal. For example, the degree value of hunger is high if an object is food.
- *Preference degree value* represents how much an agent likes an object or another agent. If the agent is threatened by another, the degree value decreases. But it increases if the agent is helped by another. The degree for a user changes depending on his/her contacting manner.
- *Decay coefficient value* is used for deciding whether an object should be memorized or not. It increases when the agent contacts an object, and decreases as time elapses. If it becomes lower than zero, the memory about the object is deleted. This oblivion contributes to saving the memory capacity and diversifying behaviors.

There are eight functional modules as follows;

Sensors. The Sensors detect stimuli from the environment to extract physical features. In our study, an agent deals with information from both the real and virtual worlds. The information from the virtual world consists of the coordinates and attribute values of objects. For the information in the real world, we use tactile sensors to recognize whether the user beats or pets the agent's body.

Reflector. The Reflector has direct mapping functions from the Sensors to the Effectors. For example, the agent blinks its eyes when it is beaten by the user.

Perceptor. The Perceptor consists of three kinds of processes. The first process recognizes objects and their states by comparing sensory data with the knowledge in the LTM. It also recognizes the types of tactile stimuli from the real world. The second one computes concern levels which are utilized for selective attention. The computation takes an account of goal's importance, object's contribution to the goal, novelty, momentum, etc. If an object's concern level exceeds its threshold, the object's information goes to the Situation-describer. The last process is learning. The agent learns whether an object or stimulus contributes to its goals or not. The learned result is memorized in the form of contribution and preference degree values in the LTM.

Situation-describer. The Situation-describer represents the outputs from the Perceptor in two ways. One is symbolic description and the other is numeric. The symbolic description represents structural relationships using case relation. Fillmore's case categories are employed to represent the case relations (Fillmore 1971). The numerical description represents locations and movements of objects, and intensities of stimuli. The Goal-creator, Emotion-generator, Planner, and Effectors refer to the Situation-describer.

Emotion-generator. The Emotion-generator generates emotions using contents of the Situation-describer 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, 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 (James 1884). This idea

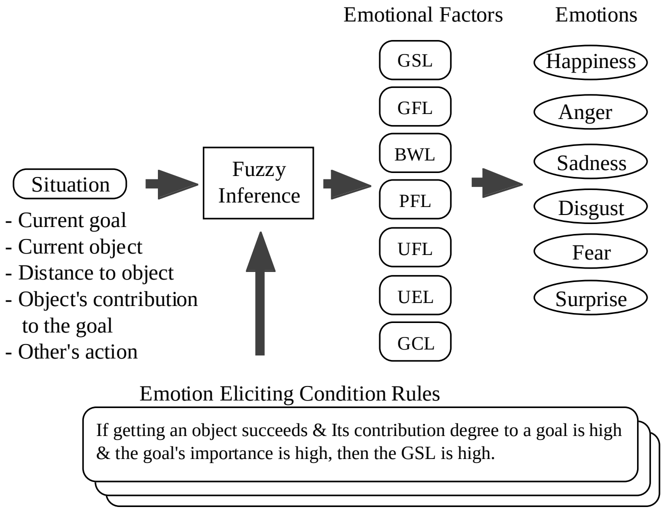

Figure 3: Framework for emotion generation.

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 (Cannon 1927). Other theorists proposed explicit components for emotion types (Ekman 1992; Johnson-Laird 1988). 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.

Goal-creator. The Goal-creator creates empirical goals using desire levels of the innate goals, the contribution and preference degrees in the LTM, contents of the Situation-describer, and emotion intensities. The goal creation process uses production rules. For example, when the degree of hunger is higher than other desires and there is an object to eat, the goal to obtain the object and eat it is created. The object's contribution degree for satisfying hunger in the LTM is used to judge whether it can be eaten or not. When the degree of hunger is higher than other desires and there is nothing to eat, the goal to search an object to eat is created. Emotion also influences the goal creation. For example, *Disgust* or *Fear* for an object creates a goal to avoid it. Every empirical goal has importance and holding degrees. Each importance degree value is computed by using the desire level, the contribution degree, and the emotion intensity. The initial value of each holding degree is 1 and it decreases as time elapses. When a goal cannot be achieved and its holding degree becomes lower than 0, then the goal is canceled. This process is useful for preventing an agent from pursuing a hopeless goal.

Planner. The Planner has action selection rules and selects a proper action depending on the situation. For example, if the goal is to eat an object and that isn't within an agent's reach, then the next action is to approach it. If the goal is to eat an object and another agent is approaching it, then the next action is to threaten the agent. Here, emotions also influence the Planner. If the goal is to eat an object and another agent is approaching it and there is fear for the agent, then the next action is not to threaten but rather to run away from the agent.

Effectors. The Effectors integrate the data from the Reflector, the Emotion-generator, and the Planner. Subsumption architecture is employed to integrate the data (Brooks 1986). The system gives priority to the input from the Reflector for the purpose of, for instance, urgent defense. Emotion expressions (e.g. facial and vocal expression) have higher priority than the planned actions. But it is possible for the Planner to suppress the reflexes and the emotion expressions. As the result of these integration, agent performs multiple actions at one time. For instance, the agent can express emotion, while drinking water.

Personality Control Parameters

Personality is an important factor for life-like characters. We apply emotions to representation of various personality. In other words, distinctive personalities are realized by differences in expressing emotion. Tuning the rules and parameters in the modules generates various personalities. Examples of personality control parameters in each module are as follows;

Innate goals. The threshold for the desire level of appetite relates to the degree of being greedy. The threshold for the desire level of user contact relates to the degree of being friendly. The increasing ratio of the desire level also leads to the same effect.

Empirical goals. The decreasing ratio of the holding degrees relates to the degree of being persistent.

Emotion-generator. The threshold for emotion is used to define how much it should be expressed. The threshold for Anger relates to the degree of being irritable. The threshold for Fear relates to the degree of being cowardly.

Planner. For instance, the threshold for the action selection rule of threat relates to the degree of being offensive.

Virtual World Characters

We applied the proposed model to characters in a virtual world, which is represented using computer graphics on a PC. A software program is implemented using the Java language and environment. There are three characters in the world. Their names are Blue, Yellow, and Pink according to their body colors. Figure 4 illustrates a whole image of the virtual world. There is a puddle in the lower center of the field. When a character is thirsty, she goes to the puddle to drink water. The user can interact with the characters in two ways. One is to give them apples. When the user puts an apple on the ground, a hungry character eats it. The other way is touching the characters via tactile sensors. A stuffed puppet illustrated in Figure 5 has built-in tactile sensors. A metaphor of the user's hand is displayed on the screen and it can be manipulated by means of a mouse. If the user selects a character using the mouse and touches the stuffed animal, the sensed information is transmitted to the character and the character reacts. The Perceptor can recognize whether the touch is a good or bad feeling for the character.

The characters express six emotions according to the situations as shown in Table 1. The emotions are represented by facial and vocal expressions. There are two levels for expressing each emotion. The levels are defined using thresholds for emotion intensities. The facial expressions are designed based on the theory proposed by (Ekman and Friesen 1975). The designs of facial and vocal expressions are different among the characters.

Examples of actions by the characters are as follows; approach a <character or object>, leave a <character or object> , look at a <character or object>, search a <character or object>, occupy an <object>, eat an apple, drink water, walk around, sleep, run away, threaten a <character or user hand>, attack a <character>, ask a <character> to give an <object>, refuse a request from a <character>, rub oneself on an <object>, ask the user to give good feeling. Here, <object> is an apple, puddle, or user hand. These actions are represented by facial and voice expressions, and body movements.

Evaluation

We conducted three experiments 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. 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

Table 1: 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 theatens of attacks.
Disgust	- Disliked object approaches.
Surpraise	- A loud noise is heard suddenly.

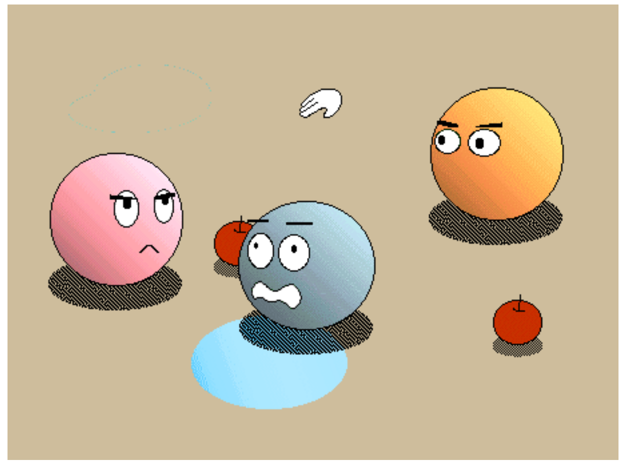

Figure 4: The virtual world.

Figure 5: A stuffed puppet, which connects with a PC, has built-in sensors to detect tactile stimuli.

Table 2: 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

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 2 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.

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 3 shows the results of the comparison analysis. The ratio was obtained using Equation (2).

$$Ratio = \frac{Number\ of\ mached\ emotions}{Number\ of\ user\ utterances} \qquad (2)$$

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 3: The result of comparison between the expressed emotions and the user estimation.

	Happ.	Anger	Sad.	Fear	Disgust	Surprise	Total
Ratio(%)	100.0	100.0	80.2	89.0	67.9	63.8	87.7

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 five-minute 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 2. This result shows an effect of the personality parameter.

Personalities pointed out by the users were shown in Table 4. The result shows that there is correlation with the parameters in Table 2. 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 2. *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.

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 5. 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.

Related Work

There have been several researches about agents with emotion. Daydreamer simulated human daydreaming using emotion and episodic memory (Mueller 1989). One of features of Daydreamer is emotional feedback system such as rationalization. For instance, Daydreamer modifies the interpretation of a goal failure in order to reduce the negative emotional state resulting from that failure. The daydreaming inference is triggered by text input, but not used to interact with its outer world.

Table 4: Personalities pointed out by users.

Character	Personalities pointed out by 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)

On the contrary, ALIVE system (Maes et al. 1994) can interact with users. It expresses emotional behavior, but doesn't have internal states of emotion.

The Cathexis model is also computational model of emotion (Velasquez 1997). Emotions, moods, and temperaments are modeled in a network composed of special emotional systems comparable to Minsky's "proto-specialist" agents (Minsky 1986). The model is influenced from Izard's system (Izard 1993). Izard arranged emotion elicitors into four categories: neural, sensorimotor, motivational, and cognitive. The Cathexis model mainly focuses on emotion generation and action selection, but it doesn't have functions for deliberative behavior and learning.

Affective Reasoner (Elliott 1992) is based on the cognitive appraisal theory. A main feature of Affective Reasoner is to express sympathetic emotions by estimating other agent's emotions and concerns. By the nature of a symbolic-based system, however, it has limitation in flexible behavior. Furthermore, it doesn't seem to create empirical goals.

Woggles and Lyotard in the Oz project (Bates, Loyall, and Reilly 1994; Reilly and Bates 1992) uses an emotion model which is also based on the cognitive appraisal theory. The model has the ability of generating flexible behaviors and creating empirical goals, but it has two main differences from ours. Firstly, the Oz model doesn't take account of mutual influence among emotions and moods. Psychologists argue that emotions and moods influence each other (Nowlis 1970; Toda 1992). For instance, an agent rarely gets angry when she is in a good mood. Secondly, the Oz model uses *behavior features* to express personality. Such a character-specific approach is able to create rich personalities, but it requires artists to rebuild program code.

Hayes-Roth, et al. have proposed a *mind model* based on her blackboard architecture and apply it to life-like characters (Hayes-Roth and van Gent 1997). The character features improvisation in interaction with users, and focuses on mood and personality rather than emotion types. Their character possesses a distinct personality which she expresses through actions based on her mood and position. The moods vary along three continuous dimensions: an emotional dimensions ranging from happy to sad, a physiological dimension ranging from peppy to tired and a social dimension ranging from friendly to shy.

Table 5: General impressions of the character's behavior. 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

Summary and Future Work

An emotion model for life-like agents was proposed in this work. The model consists of reactive and deliberative mechanisms. The former generates low-level instantaneous responses to stimuli that come from the real and virtual worlds. The latter mechanism especially focused on emotions and personalities. A basic idea of the model has come from a psychological theory. The concept of the theory is based on interactions between cognitive and emotional process in a mind. The model realized life-like agents with motivations and emotions. The authors applied it to the characters in a virtual world. Evaluation results showed that the proposed method is effective to give users the illusion of life.

One of our future work is adding a function of processing long term contexts. This function is required to smoothly communicate with users. The history of interaction will be memorized to generate more intelligent behavior by means of the function. For example, an agent, who is able to use the conversation history, will not repeat the same utterance. We also have plans to realize mixed emotion, emotion transition and mood. Then, tuning method of personality parameters will be established.

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