Behavior Decision Model Based on Emotion and Dynamic Personality

Chan-Woo Yu*, and Jin-Young Choi**

* School of Electrical Engineering and Computer Science, ASRI, Seoul National University, Seoul, Korea
(Tel : +82-2-872-7283; E-mail: cwyou@neuro.snu.ac.kr)
** School of Electrical Engineering and Computer Science, ASRI, Seoul National University, Seoul, Korea
(Tel : +82-2-872-7283; E-mail: jychoi@neuro.snu.ac.kr)

Abstract: In this paper, we propose a behavior decision model for a robot, which is based on artificial emotion, various motivations and dynamic personality. Our goal is making a robot which can express its emotion human-like way. To achieve this goal, we applied several emotion and personality theories in psychology. Especially, we introduced the concept of dynamic personality model for a robot. Drawing on this concept, we could make a behavior decision model so that the emotion expression of the robot has adaptability to various environments through interactions between human and the robot.

Keywords: Artificial Emotion, Personality, Robot Behavior Decision Model, Psychology

1. INTRODUCTION

Nowadays many robot researchers are concentrating on developing various types of robots that can be used in real world. Recently several types of humanoid robots were developed. They can walk, recognize people, shake hands and hold a simple conversion with people around them. To interact with people and react to various stimuli from surrounding environment, the robot should decide which action is adequate to given situation. Lately most of behavior decision techniques have been depended on cognitive information. However the behavior decision system which reflects cognitive information only, has limited capability in dealing with various environment changes and generating more human-like actions. Emotion system can compensate these weak points of cognitive system and play an important role in making an intelligent robot act in a more acceptable way to human. Important concepts of emotion systems are 'Emotion', 'Mood', 'Motivation' and 'Personality'. Each component functions as a module which composes total behavior decision model. By concocting these components, we can make various kinds of emotion models. In this research, we prefer to set our focus on the personality component.

Until now many robot researchers have proposed mind models for a robot. Breazeal[1] developed a robot system called KISMET, which expresses emotion by changing its facial expression. In KISMET, the emotion system assesses and signals the value of immediate events in order to appropriately regulate and bias the cognitive system. Likewise, Miwa[2] suggested a mental model for humanoid robots for human friendly communication. By taking in this mind model, a robot became to have a capability to learn environmental factors of personality. Kshirsagar[3] suggested a system that allows the design of personality for emotional virtual human. They adopted FFM(Five-Factor Model) in psychology and used Bayesian Belief Network to realize the model. Nakajima [4] proposed an embedded mind model as a strategy for improving the effectiveness and efficiency of human-machine collaboration. To define a personality space, they adopted Reeves & Nass's personality model, which suggested friendliness and dominance as two major attribute of personality. Meanwhile, Yingying[5] represented personality with the evaluation function to prevent conflict of the usual multi-robot system. With different decision made by different personality, they realized the self-organizing coordination of multi-robot system. Most of emotion-generating systems including systems referred above have mainly concentrated on expressing appropriate emotion for a certain situation. Accordingly, their capabilities for adapting to time varying environment and changing its response toward user's preference are not enough.

In this paper we propose a robot's behavior decision model based on emotion and dynamic personality, which aims for a virtual pet robot called VPET. Especially we applied personality theories in psychology to constructing dynamic personality model. The dynamic personality acts an important role in diversifying behavior and improving adaptability to the surrounding environment through interactions between human and robot. Essential components for behavior decision are stimulus, motivation, emotion and personality. Every stimulus from internal or external environment changes emotion or makes a motivation. The generation of motivation is also affected by emotion changes. These motivations are expressed through facial expression and body actions. In this sequence, the personality operates on generating emotion and deciding behavior, finally it diversifies the robot's behavior.

2. EMOTION AND PERSONALITY

Why should a robot have emotion and show its emotion states? For human, emotion acts as a signal that indicates desires of human body[6]. Facial expression, moreover, shows the condition of brain and the internal state. In the case of animal, they communicate their intentions(courtship, obedience, warning, challenge, etc.) to others through emotion expression. By applying these functions of emotion to robot development, we hope that it becomes possible to create a robot which acts more human-like way.

Paul Ekman[7] classified human emotion into six categories (Happiness, Sadness, Anger, Surprise, Fear, and

Disgust) and described the specific situations that each emotion occurs. We adapted his research results and converted them into a form suitable to human-robot interaction. Through this process we had some emotion revealed when given conditions are satisfied.

Five-Factor Model (FFM) is a recently suggested psychological theory that explains human personality[8]. According to this theory human personality is composed of five factors. These values of five components are independent each other and the entire personality is determined by how high value of each component one person has. In our research we adapted this theory to constructing robot's personality structure. By utilizing personality theory for our model, we made the generation of emotion and motive, the change of emotion, the behavior decision and the emotion expression conducted in more human-like manner. Particularly we made the robot's behavior have adaptability as the interaction between human and robot progresses by changing each personality component along emotion continuance, perceptions of environment and reward or punishment stimulus.

3. ARTIFICIAL MIND MODEL

3.1 Overall structure of VPET.

Fig.1 shows the overall structure of interaction between environment, including users, and VPET. Important components of our model are emotion, motivation, behavior decision module and personality. Various stimuli from external environment results in the change of VPET's emotion. For the particular stimulus, the details of emotion change are affected by personality and internal state of VPET. Motivation means an underlying cause of behavior. Especially in our model, it means the desire to express emotion state. The actions that VPET shows externally are determined by behavior decision model. It selects the most pertinent motivation from several motivations generated by emotions and external stimulus. Personality plays a core role in our model to generate adaptive emotion behavior suitable to circumstance. It doesn't only determine how high emotion value is generated for a certain stimulus, but also affect on selecting final motivation expressed externally. The following are detail descriptions about the organization and the functions of each component.
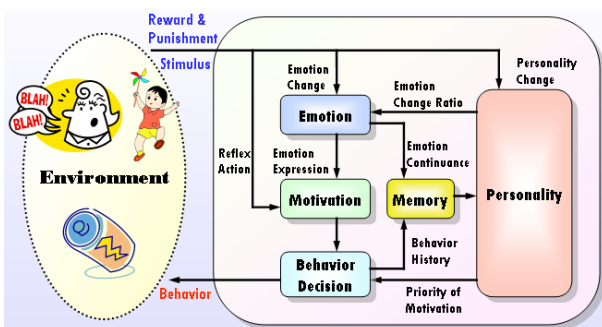

Fig. 1 Interaction structure between environment and VPET.

3.2 Memory of VPET (attitude toward environment)

For human case, the past experience is the one of primary factors in deciding which action someone should do now. Like human, it is important that a robot has memory space for adaptive behavior. As a part of memory, we suggest to utilize attitude toward external environment. In communicating with people, our attitude toward the other affect on deciding how civil to the other one. Likewise we selected several cases in which a robot's attitude toward users increases or decreases (See Table 1).

Table 1 Attitude change condition of VPET

Object	Variation	Condition for variation
A user on Interaction	Favor Increase	The user gives an award to VPET.
	Favor Decrease	The user gives a punishment to VPET.

3.3 Emotion of VPET

We define several situations in which specific emotion emerges by adapting Ekman's emotion theory. Ekman's research, however, focused on human emotion expression, so direct application of his theory isn't suitable in robot's case. Therefore we converted the situation more suitable to the interacting situation between human and robot.

Six emotion components have its own occurrence condition as shown in table 2. There are 6 kinds of stimulus and for each stimulus, two situation factors affect on determining which emotion factor emerges. One of the situation factors is VPET's attitude, mentioned in previous chapter, toward user who is in interaction with VPET. If VPET has positive attitude, it will express favorable emotion(pleasure) more often than when it has negative attitude. The other situation factor is the recognition of VEPT. Whether VPET is recognizing the user or not has an influence on generation of surprise. These situation factors make VPET express diverse emotions for the same stimulus. Final modification factor is personality, which will be described in the further chapter.

Except the condition mentioned above, internal states of VEPT(fatigue, exhilaration, hunger, and satiation) also generate emotion. While fatigue and huger increase negative emotion(sadness, anger, etc.), satiation and exhilaration increase positive emotion(pleasure).

3.3 Motivation of VPET

VPET has two kinds of motivations. The one is internal motivation. Internal motivation arises from hunger, fatigue and emotions generated by internal stimulus. Each motivation has its own priority determined by Maslow's theory about the

Table 2 Emotion change by external stimulus

Situation \ Stimulus	Recognize User		User's approach				User's step backward				Reward				Punishment			
Attitude toward user	+	-	+		-		+		-		+		-		+		-	
Recognition			O	X	O	X	O	X	O	X	O	X	O	X	O	X	O	X
Emerging Emotion	W5	W3 W6	W5		W3 W6		W1		W5		S5	S4 S5	W5	S4 W5	W1 W6 W2	S4 W1 W6	W1 S6 W3 S2	S4 W1 S6 W3

* + : A situation that VPET has positive attitude toward the user,   - : A situation that VPET has negative attitude toward the user

* O : A situation that VPET is recognizing the user.   X : A situation that VPET is not recognizing the user.

* S: Strong emotion(high numerical value), W: Weak Emotion(low numerical value)

* 1: Sadness, 2: Anger, 3: Disgust, 4: Surprise, 5: Pleasure, 6: Fear

rank of desires[9]. The other kind of motivation is external motivation. It includes the positive reflex to the reward stimulus given when VPET doesn't recognize the user, and the negative reflex to the punishment stimulus. Emotions generated by external stimulus are also elements of external motivation.

3.4 Personality of VPET

Our artificial personality module is composed of four components: neuroticism, extroversion, originality and agreeableness. Like in the emotional case, original personality theories are not proper to organize robot's artificial personality. So we defined new functions of each personality component similar to human case (See table 3). Neuroticism and Originality is utilized for determining the magnitude of emotion generated by stimulus. If a robot has high neuroticism, it may feel sad easily. So users should pay attention to the emotional variation when they give a punishment to VPET. The emotion of a robot which has high originality changes readily. Therefore there are many emotion factors whose value is higher than threshold and so the robot seems to reacts to stimulus sensitively.

Other two factors, extroversion and agreeableness, are used to determine behavior. Agreeableness is a significant factor in deciding which motivation should be expressed externally. A robot that has high agreeableness tends to select external motivation because it is more interested in other's needs and seeking harmony with people. Extroversion affect on determining how to express the selected motivation. Having high extroversion value, a robot will express its motivation more actively. If a robot which has low extroversion value watches its owner, it will just walk to him. Another robot which has high extroversion value, however, will run to him.

In original personality theory, the numerical values of personality factors are innate. Therefore the personality factors don't have any interrelationship with environment or experience. We, however, established the personality module as storage of data from experience. Consequently, the numerical values of personality factors illustrated above are not constants. If a robot receives a reward for its last behavior, it will change its personality factors in the direction of selecting the last behavior more often. Or if a robot is punished for its last behavior, it will change its personality factors in the direction of selecting the last behavior less often. The examples of detail conditions for the personality change

are presented in table 4. These personality changes make behaviors of a robot more reasonable and acceptable for human.

Table 3 The effects of personality

P. Factor	Value	Effect
Neuroticism	High	High sensitivity on sad situation
	Low	Low sensitivity on sad situation
Extroversion	High	Express motivation in active way
	Low	Express motivation in passive way
Originality	High	High variation of emotion value
	Low	Low variation of emotion value
Agreeableness	High	Set priority to external motivation in the behavior decision process
	Low	Set priority to internal motivation in the behavior decision process

Table 4 Condition for increase/decrease of personality factor

P. Factor	+/-	Condition
Neuroticism	+	Negative emotions are continued for a certain period.
	-	Positive emotions are continued for a certain period.
Extroversion	+	Active(Passive) expression for a motivation is rewarded(punished).
	-	Active(Passive) expression for a motivation is punished(rewarded).
Originality	+	When reactions of the user has consistency.
	-	When reactions of the user doesn't have consistency.
Agreeableness	+	A behavior selected by external(internal) motivation is rewarded(punished).
	-	A behavior selected by external(internal) motivation is punished(rewarded).

3.5 Behavior Decision of VPET

Behavior decision is a process of selecting a behavior among various motivations generated at the same time. The final motivation, which is expressed externally, is either a internal motivation or a external motivation. One of the personality factors, agreeableness functions as a yardstick in this process. Eq.(1)~Eq.(2) shows how the final motivation is selected. As you can see in these equations, the robot which has high external motivation will express the external motivation more often than internal motivation.

$$Temp(ag) = \frac{1}{1+\exp(-ag)} \ , when\ ag\ is\ the\ value\ of\ agreeableness\ factor \quad (1)$$

$$Final\ motivation = \begin{cases} \text{int} eral\ motivaion\ , & if\ rand\ >\ Temp(ag) \\ external\ motivation\ , & else \end{cases} \quad (2)$$

$*\ rand\ is\ a\ random\ number\ between\ 0\ and\ 1.$

4. SIMULATION AND RESULTS

4.1 Simulation Environment

Simulation environment for VPET is displayed in Fig. 4. Fig.4 (a) is a window that indicates total information about VPET. Through this window the user can identify VPET's internal states(emotion, personality etc.) and check up how VPET reacts to the user's actions. Fig.4 (b) shows the actions that users can choice. Each action of the user generates emotion in VPET, and changes the values of the personality factors.
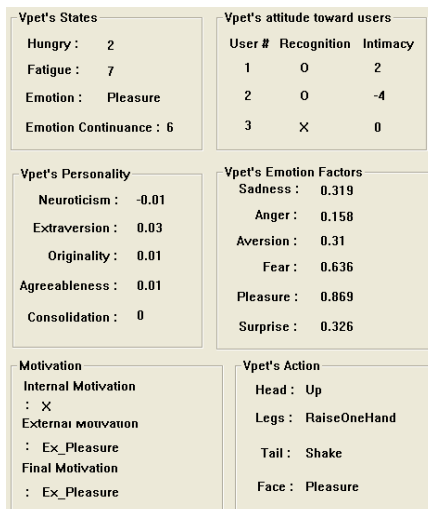

(a) Total information about the VPET.
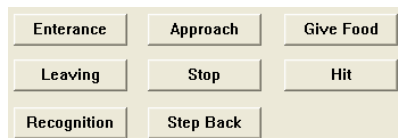
(b) User's actions for interacting with the VPET.

Fig. 2 Simulation environment for VPET.

4.2 Effects of personality on emotion change and behavior

Each component of personality has distinctive effect on emotion change and behavior decision. Fig. 3, for example, shows the influence of neuroticism on emotion change. Fig. 3(a) show the emotion variation of the robot which has low neuroticism value(-0.7), and Fig. 3(b) is the results of a robot which has high neuroticism value(0.7). For the same stimulus(reward and punishment), higher sad emotion is generated in the robot whose neuroticism value is high.

The effect of extroversion, as another example, is shown in Fig. 5. The behavior of a robot is composed of three independent parts: head action, legs action, tail action. For each part, a robot has several choices and the only one action is selected at each time step. In each action, the choice located in higher layer means a more active action than the one in lower layer. Fig. 4(a) indicate the behavior selection of a robot whose extroversion value is low(-0.7), and Fig. 4(b) shows the opposite case. As turned up in the figure, the robot which has higher extroversion value tends to express their emotions in more active way.
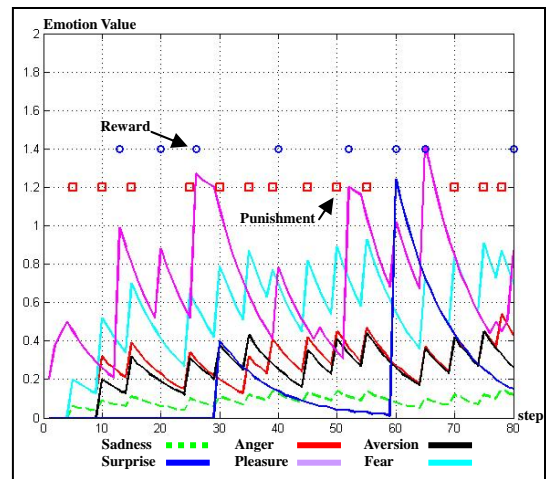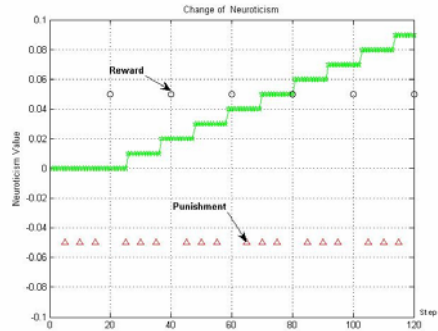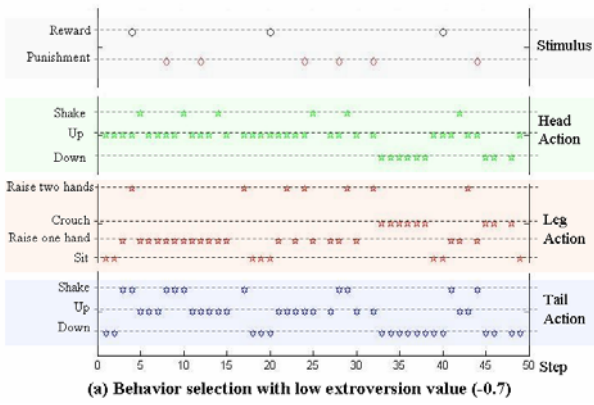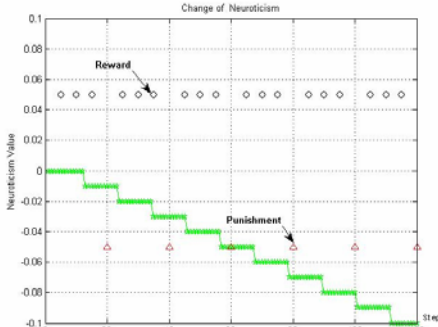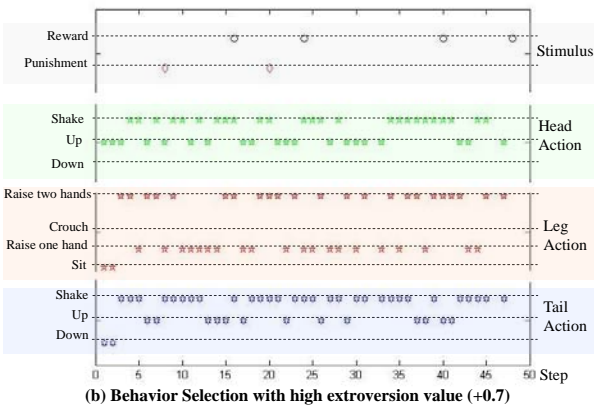

(a) Change of Emotion (Neuroticism = -0.7)
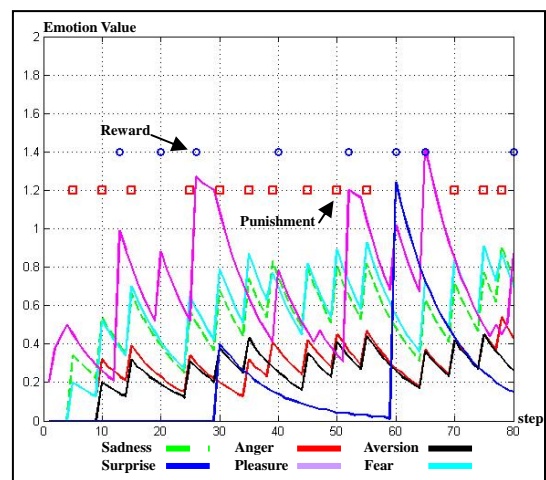
(b) Change of Emotion (Neuroticism = 0.7)

Fig. 3 Effect of neuroticism on the change of emotion.

(a) Behavior selection with low extroversion value (-0.7)

(b) Behavior Selection with high extroversion value (+0.7)

Fig. 4 Effect of extroversion on behavior decision

4.3 Change of personality

In our paper, the change of personality factor plays a core role in generating adaptive behavior of a robot. Hence, it is important to clear the exact situation in that the personality changes. As examples, we present the cases of neuroticism and extroversion. Fig.4 shows how neuroticism undergoes changes by reward and punishment stimulus. In the Fig .4(a), we gave more punishments on VPET than rewards. As shown in table 2, the punishment is the one of main causes generating sad emotion. Since the sad emotion is a main factor of neuroticism increase, the robot punished often will increase its neuroticism value. On the other hand, the neuroticism value of the robot rewarded often will decrease (See Fig. 4(b)).

Fig.5 indicates how the extroversion value changes through reward and punishment. At each time step, three parts of VPET – head, legs, tail – express their unique actions. For each part, '+' action means that the VPET expresses its motivation in active way, and '− ' action means it express its motivation in passive way. Accordingly, as shown in Fig. 5(a), if we give a reward to VPET when it performs lots of active actions, the extroversion value will increase so that the robot can show active actions more often in the future. In reverse, if we give a reward to VPET when it performs lots of passive actions, the extroversion value will decreases so that the robot can show passive actions more often in the by-and-by as shown in Fig. 5(b). If we punish the robot, the variation will happen in opposite direction.

(a) Neuroticism increment by reward & punishment

(b) Neuroticism decrease by reward & punishment

Fig. 4 Change of neuroticism by reward & punishment

(a) Extroversion increment by reward & punishment

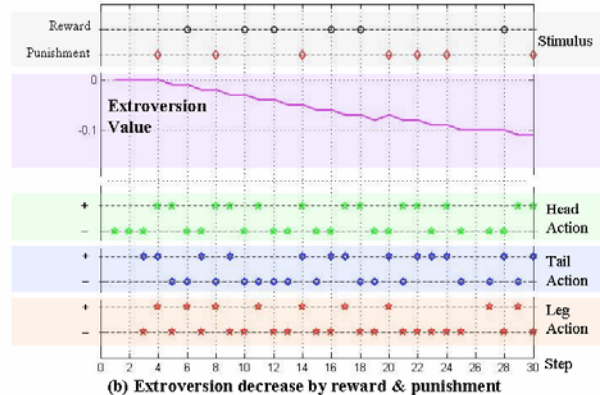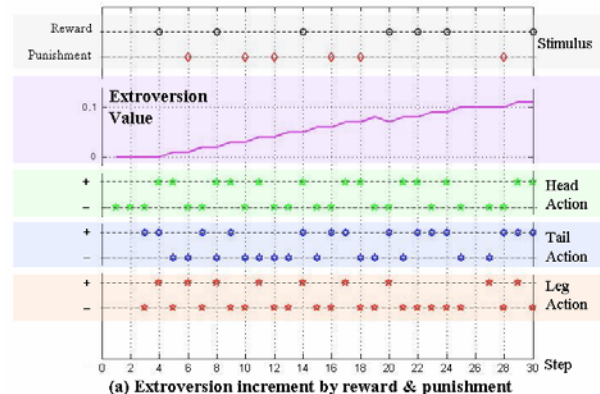**(b) Extroversion decrease by reward & punishment**

Fig. 5 Change of extroversion by reward & punishment

In the Fig. 6, the total information about VPET is indicated. As rewards and punishments are given by a user, the emotion

values changes and the changes are reflected in behavior decision. Personality doesn't change as quickly as emotion does. Therefore the user will not be able to recognize the alteration of personality easily. However, the behavior pattern of VPET changes gradually as the interaction between the user and itself goes by. In a moment, after many time steps passed by, the user will find that their responses toward VPET are reflected in the behavior decision process.
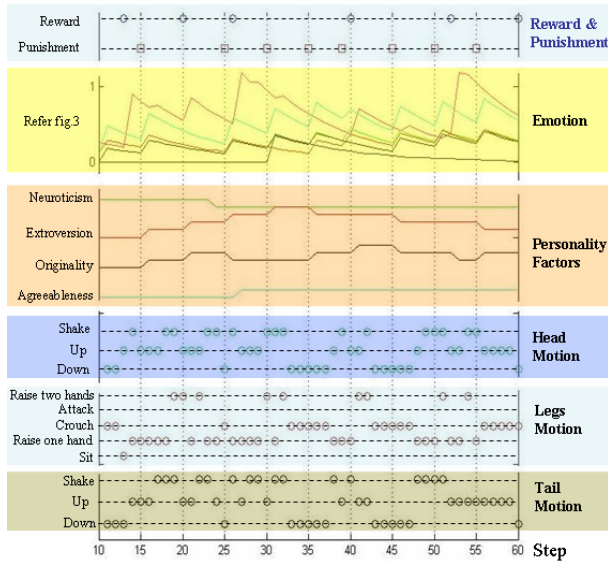

Fig. 6 Change of emotion, personality and behavior

5. CONCLUSION

In this paper we have proposed a new behavior decision model of a robot for expressing emotion. The emotion behavior is conducted through expressing motivation decided by emotion and personality. We applied personality theories to defining artificial personality module and its change conditions. The robot memorizes experiences in interaction with human through personality change. And personality change let a robot express emotion in more reasonable way. In the future, we will continue our researches about how to make a robot express their emotion more human-like manner.

ACKNOWLEDGEMENT

REFERENCES

[1] C. Breazeal, "Function meets style: insights from emotion theory applied to HRI" *IEEE Trans. On systems, Man, and Cybernetics*, Vol.34, No.2, pp.187-194, 2004

[2] H. Miwa, T. Okuchi, K. Itoh, H. Takanobu, A. Takanishi, "A new mental model for humanoid robots for human friendly communication" *Proc. of the 2003 IEEE international conference on robotics & automation*, pp. 3588-3593, 2003

[3] S. Kshirsagar, "A multilayer personality model", *Proc. Of 2nd international symposium on smart graphics*, pp.107-115, 2002

[4] H. Nakajima, et. al., "The functionality of human-machine collaboration systems – mind model and social behavior" *Systems, Man and Cybernetics, 2003. IEEE International Conference on*, vol.3, pp.2381-2387, 2003

[5] Ding Yingying, Han Yan, Jiang Jing-ping, "Self-organizing multi-robot system based on personality evolution" *Systems, Man and Cybernetics, 2002 IEEE International Conference on*, vol.5, 2002

[6] R. Plutchik, *Emotions and Life*, Amer Psychological Assn, 2002

[7] Paul Ekman, *Emotion Revealed: Recognizing Faces and Feelings to Improve Communication and Emotional Life*, Henry Holt & Co, 2004

[8] R. LIEBERT, *Personality Strategies And Issues*, Thomson Learning, 1998

[9] A. Maslow, *Motivation and Personality*, Viking Press, New York, 1970