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Robotic Emotional Model with Personality Factors based on Pleasant-Arousal Scaling Model

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***Abstract*— Emotion and personality are significant factors in communication. In general, during a decision making process in human-human communication, emotional factors will be affected not only the logical thinking, but also the emotional responses. Furthermore, personality gives individual differences among people in behavior patterns, cognitive process and emotional responses. In this paper, we propose the three stages (core affects, emotion and mood) robotic emotional model with OCEAN model as the personality factors based on 2D (Pleasant-Arousal) scaling model. The emotion states in proposed model are represented on pleasant-arousal plane. The results from simulation experiment show that the proposed model is able to generate the different emotional properties based on the personality factors.**

I. INTRODUCTION

Researchers in psychological fields have been tried to reveal the human psychological functions such as neuropsychology, developmental psychology and cognitive psychology [1], [2], [3], [4]. In the past decades, computer scientists have been attempted to establish the human psychological functions on the computer. Specifically, in order to acquire the human functions, the researches of "Intelligence" as neural networks and fuzzy systems [5], [6], and the researches of "Cognition and Perception" as image processing and voice recognition have been discussed and developed [7], [8]. In addition, to discuss "humanity" from the point of view of the psychology, one of the significant elements is the emotion. In general, during a decision making process in human-human communication, it will be affected not only the logical thinking factors, but also the emotional factors [9]. This emotional function is one of the distinct differences between human and robot.

Emotional functions are complex phenomena of human, that consists of different components such as physiological, cognitive and motivational processes. Some researchers in psychological field operate under the assumption of a fixed number of emotions [10], whereas others consider the regions or prototypical trajectories within a continuously defined state space of psychological concepts as basic forms of descriptions for emotions and simpler affective states [11]. Moreover, several psychological scientists argue that human emotion is composition result of core affects, basic emotions and moods [12], [13], and these are affected each other. Based on these psychological backgrounds, several types of computational based emotional models have been introduced [14], [15]. Russell et al. [16] proposed a 2D (pleasure-arousal) scaling model that shows the relationships between facial expressions and emotions.

In the discussion of emotional factor, the concept of personality is regarded as one of the essential factors. In general, personality gives individual differences among people in behavior patterns, cognitive process and emotional responses [17], [18]. Smith et al. argue that human beings are tendency to recall emotions from several information based on their knowledge and experience [19]. The effect of personality and emotional factor for behaviors has been studied, and proposed several models. For instance, from the view point of behaviors [20] and various rule-based models [21], probabilistic models [22] have been introduced. Costa et al. [23] introduced five factors (Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism) model called OCEAN model. In addition, several psychologists have been discussed about relationships between human emotional factor and personality factor [24], [25], [26], [27]. Mehrabian utilized the five factors of personality to represent the Pleasant-Arousal-Dominance (PAD) temperament model [28]. The relationship between five factors of personality and PAD model is derived through the linear regression analysis [29]. Han et al. [14] employed five factors of personality to a 2D (pleasure-arousal) scaling model that is introduced by Russell [16] to represent a robotic emotional model. This model generates a robot mood state from the human facial expression information. However, human emotional state is generated by not only facial expression, but also several stimulus from the environment.

In this paper, based on 2D (pleasure-arousal) scaling model with OCEAN model that is proposed Han et al. [14], we propose a three stages (core affect, emotion and mood) robotic emotional model. In this model, we consider the Ortony, Clore and Collins (OCC) model [30] for appraisal the emotional information of events, objects, desirability, praiseworthiness to handle not only human facial expression information, but also the several modalities. This paper is divided as follows, Section II describes the relationships between emotional factor and personality factor. In section III presents the proposed robotic emotional model. In section IV presents the simulation experiment of proposed model. Concluding remarks are finally presented in Section V.

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II. RELATIONSHIPS BETWEEN EMOTION AND PERSONALITY

A. Five Factors of Personality

Personality is one of the key factors to construct the individual differences, such as perception, motivation and cognition [31], [18]. Moreover, the differences of personality will influence and intervention to individual psychological phenomena, for instance, perceives emotion and emotional behaviors. In the past, several models of personality have introduced. One of the widely accepted personality models is five factors (Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism) model that is proposed by McCrae et al. [32]. The five factors of personality were defined through a statistical procedure, which was used to analyze how ratings of various personality traits are correlated for general humans. Table I shows the five factors of personality and its descriptions [23]. In this paper, we utilize five factors model to represent the robotic personality.

B. Emotional Models and Personality Factors

Mehrabian utilized the five factors of personality to represent the emotional information by Pleasure?Arousal?Dominance (PAD) temperament model [28]. The relationship between five factors of personality and PAD model is derived through the linear regression analysis [29]. This result is summarized as three equations of temperament, which includes pleasure, arousal, and dominance as followings;

$$P_\alpha = 0.21E + 0.59A + 0.19N \tag{1}$$

$$P_\beta = 0.15O + 0.3A - 0.57N \tag{2}$$

$$P_\gamma = 0.25O + 0.17C + 0.6E - 0.32A \tag{3}$$

,where P_α, P_β and P_γ represent the value for pleasant axis (α-axis), arousal axis (β-axis) and dominance axis (γ-axis), respectively. O, C, E, A, and N (where, $O, C, E, A, N \in [-1, 1]$) represent the five factors of personality as openness, conscientiousness, extraversion, agreeableness and neuroticism, respectively.

Russell et al. [16] proposed a 2D (pleasure-arousal) scaling model that shows the relationships between human facial expressions and emotions based on human study. The 2D scaling model can be considered as the part of PAD model. Han et al. [14] employed five factors of personality to a 2D scaling model to represent a robotic emotional model (Fig. 1). This emotional model is composed by the user emotional state recognizer and the robotic mood state generator, and utilized Eqs. (1) and (2) to generate the robotic emotional states from the human facial expression information. In this paper, we also utilize the five factors model with a 2D scaling model to represent the robotic emotions. The details of proposed robotic emotional model will be shown in Section Ⅲ.

TABLE I: Five Factors of Personality [23].

Factor	Descriptions
Openness	Open mindedness, interest in culture.
Conscientiousness	Organized, persistent in achieving goals.
Extraversion	Preference for and behavior in social situations.
Agreeableness	Interactions with others.
Neuroticism	Tendency to experience negative thoughts.

Fig. 1: Mapping of prototype emotions based on pleasant-arousal plane [16].

III. EQUATIONS OF ROBOTIC EMOTIONAL MODEL

In general, human emotional states are generated by not only facial expression, but also several stimulus from the environment. In addition, researches in the human psychology field have been expected that the human emotional function is composition result of core affect, emotion and mood state [12], [13]. Thus, in this paper, based on 2D (pleasure-arousal) scaling model with OCEAN model that is proposed Han et al. [14], we propose a three stages (core affect, emotion and mood) robotic emotional model. In this model, we consider the Ortony, Clore and Collins (OCC) model [30] for appraisal the emotional information of events, objects, desirability, praiseworthiness to handle not only human facial expression information, but also the several modalities. The appraisal model based on OCC model is described as a following vector;

$$\Omega = \begin{bmatrix} \omega_1 \\ \vdots \\ \omega_m \end{bmatrix}, \quad \forall_i \in [1, m] : \omega_i \in [0, 1] \tag{4}$$

here, m represents the number of basic emotions. Basically, ω is defined based on OCC model for any information. Previously, we have proposed the emotional model that is composed core affects, emotions and mood states. This model handles six basic emotions (happy, sad, angry, fear, disgust and surprise) based on Ekman's model [10].

Based on proposed emotional model (Fig. 2), we defined the following mathematical models. First of all, the system observes multi-modal inputs $I^{MI}_{(t)}$, such as visual, sound and

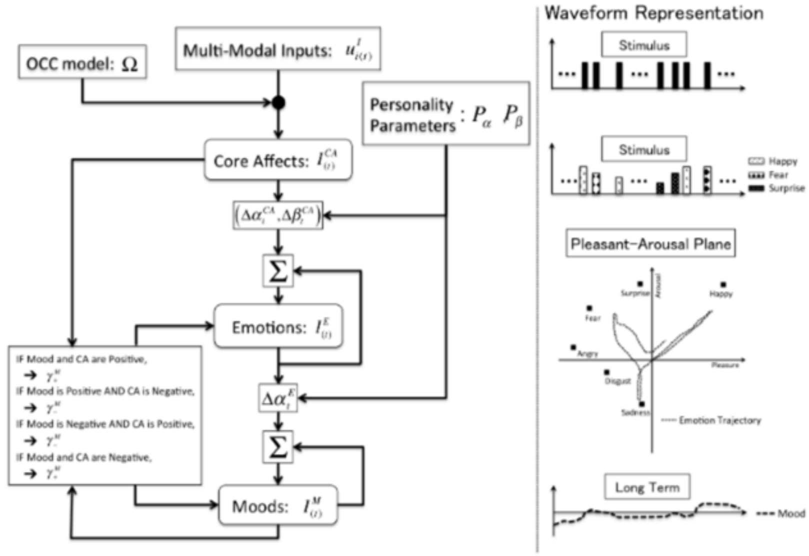


Fig. 2: The structure of Emotional Models and waveform representation.

contextual information;

$$I^{MI}_{(t)} = \begin{bmatrix} u_1 \\ \vdots \\ u_m \end{bmatrix}, \quad \forall_i \in [1, m] : u_i \in [0, 1] \tag{5}$$

here, m represents the number of basic emotions, and each modal has same vector form. As a next step, OCC model extract emotional intensities of each information as a following;

$$U_{ij(t)} = I^{MI}_{i(t)} \Omega^{\mathrm{T}}_{j(t)} \tag{6}$$

here, Ω denotes emotional intensities that are determined by OCC model. Exponential T denotes a transpose matrix. We utilize the diagonal elements of $U_{ij(t)}$ as the state of core affects $I^{CA}_{(t)}$.

$$I^{CA}_{(t)} = \begin{bmatrix} U^I_{11(t)} \\ \vdots \\ U^I_{mm(t)} \end{bmatrix}, \quad \forall_i \in [1, m] : U_i \in [0, 1] \tag{7}$$

In this paper, we utilize six basic emotions (Happy, Sadness, Angry, Fear, Disgust, Surprise). Therefore, core affects $I^{CA}_{(t)}$ will be written as a following;

$$I^{CA}_{(t)} = \begin{bmatrix} ca^H \\ ca^S \\ ca^A \\ ca^F \\ ca^D \\ ca^{Sur} \end{bmatrix} = \begin{bmatrix} \text{intensity of Happiness} \\ \text{intensity of Sadness} \\ \text{intensity of Anger} \\ \text{intensity of Fear} \\ \text{intensity of Disgust} \\ \text{intensity of Surprise} \end{bmatrix}, \tag{8}$$

$$ca \in [0, 1]$$

Han et al. [14] proposed the interactive robotic emotional variables $(\Delta\alpha, \Delta\beta)$, which represent the reaction from current emotional intensities on the pleasant?arousal plane. These variables are based on neutral intensity, happiness intensity, anger intensity and sadness intensity. We extent their four emotional factors model to six emotional factors model as core affect-emotion transfer coefficients, such that;

$$\begin{aligned} \Delta\alpha^{CA}_t = \quad & 0.9ca^H - 0.2ca^S - 0.9ca^A \\ & -0.8ca^F - 0.5ca^D - 0.2ca^{Sur} \end{aligned} \tag{9}$$

$$\begin{aligned} \Delta\beta^{CA}_t = \quad & 0.9ca^H - 0.5ca^S + 0.2ca^A \\ & +0.7ca^F - 0.2ca^D + 0.9ca^{Sur} \end{aligned} \tag{10}$$

here, variable $\Delta\alpha$ and $\Delta\beta$ represent the value for pleasant axis (α-axis) and activation axis (β-axis), respectively. In addition, coefficient of each emotional intensity is determined by Fig. 1.

The state of emotion $I^E_{(t)}$ is calculated as a following;

$$I^E_{(t)} = \tanh\left[\gamma^M \left(I^E_{(t-a)} + \left(P_\alpha \cdot \Delta\alpha^{CA}_{(t-a)},\ P_\beta \cdot \Delta\beta^{CA}_{(t-a)}\right)\right)\right] \tag{11}$$

where, γ^M $(0 \leq \gamma^M \leq 1.0)$ is the suppression rate from mood state. It depends on combination of current mood and core affect, the value of γ^M will be changed (e.g., if mood and emotional attribution are positive, γ^M takes a high value. If the mood is positive, but emotional attribution is negative, γ^M takes a low value.). a takes an arbitrary value as a time delay. P_α and P_β are defined as Eqs. (1) and (2).

In general, mood state will be taken positive or negative state [33]. We assume that it can be represented on pleasant axis in Fig. 1. Therefore, emotion-mood transfer coefficient $\Delta\alpha^E_t$ is defined as a following;

$$\Delta\alpha^E_t = I^{E(\alpha-\text{ axis})}_{(t)} \tag{12}$$

Finally, mood state is determined as a following;

$$I^M_{(t)} = \tanh\left[\gamma^M \left(I^M_{(t-a)} + \left(P_\alpha \cdot \Delta\alpha^E_{(t-a)}\right)\right)\right] \tag{13}$$

where, γ^M $(0 \leq \gamma^M \leq 1.0)$ is the suppression rate from mood state. a takes an arbitrary value as a time delay. P_α is defined as Eq. (1).

IV. SIMULATION EXPERIMENT

This section presents simulation experiment of the proposed robotic emotional model. It will be shown that even if the input information are same, the model is able to generate the different emotional information due to the different personality factors.

A. Experimental Condition

Through the simulation experiment, the multi-modal inputs are prepared as the test data, these are not generated from the sensor devices, to get the same input values with the same sequence. In addition, we assumed that the each input is assigned the specific emotional attribution/Intensity Ω by OCC model as Table II. Table IV shows the parameter settings of suppression ratio γ^M in Fig. 2. Due to the proposed robotic emotional model is defined on 2D (pleasant-arousal) scaling model, the personality factors are used four factors (Openness, Extraversion, Agreeableness and Neuroticism) out of five factors of OCEAN model with Eqs. 1 and 2. For this simulation experiment, we define four types of personality as Table III. Furthermore, we define the positions of emotional factors on 2D plane as Fig. 3. These positions of emotional factors are related to coefficients of Eqs. (9) and (10). Here, the output from Eq. (11) is mapped on 2D plane, and it will be moved to the specific position based on effect from core affects. For instance, if the output from Eq. (11) is close to position $(\alpha, \beta) = (0.9, 0.9)$, the intensity of Happy is higher than other emotions.

B. Simulation Result

As shown in Fig. 2, multi-modal inputs and core affects are not affected personality factors. Therefore, these outputs show the same results as Figs. 4 and 5. The states of core affects are generated from multi-modal inputs based on predefined weight as OCC model that is shown in Table II. Fig. 6 shows the trajectory of emotion state with different personality factors. Here, the symbols (a) to (f) in the Fig. 6 are corresponding to the symbols (a) to (f) in Fig. 5. Due to P_α in Eq. (1) and P_β in Eq. (2), each figure shows the quite different result. As mentioned above, as long as there are the effects from core affects, the output of emotion state approaches to the position of specific emotional factor on 2D plane. Fig. 7 shows the outputs of mood state based on α-axis of emotion state. Comparing with Figs. 7(c) and 7(d), it is clear that the personality factors play an important role to make the different emotional properties, and the functions of personality have successfully integrated in proposed robotic emotional model.

From the results in Figs. 6 and 7, for instance, it can be regarded the type 2 personality makes the rich emotional expression character, and it is sensitive to the environment, the type 4 personality makes calm character, and it has the tolerance about influence from the environment.

V. CONCLUSION

This paper proposed the robotic emotional model with personality factors based on core affects, emotion and mood using 2D (pleasant-arousal) plane. In this model, we utilized the Ortony, Clore and Collins (OCC) model for appraisal

TABLE II: Emotional intensity Ω for test data.

	Emotional Intensity Ω					
	Happy	Sad	Angry	Fear	Disgust	Surprise
input 1	0.70	0.00	0.00	0.00	0.00	0.00
input 2	0.00	0.60	0.00	0.00	0.05	0.00
input 3	0.00	0.00	0.50	0.05	0.00	0.00
input 4	0.00	0.00	0.05	0.40	0.00	0.00
input 5	0.00	0.05	0.00	0.00	0.70	0.00
input 6	0.00	0.00	0.00	0.00	0.00	0.70

TABLE III: Four types of personality.

	Type 1	Type 2	Type 3	Type 4
Openness	0.40	0.90	0.50	0.50
Extraversion	0.30	0.70	0.10	0.20
Agreeableness	0.30	0.50	0.80	0.20
Neuroticism	-0.20	-0.60	0.20	-0.40

TABLE IV: Parameter settings of suppression ratio γ^M .

	Input	Positive Mood	Negative Mood
γ^M	Positive Mood	0.95	0.60
	Negative Mood	0.60	0.95

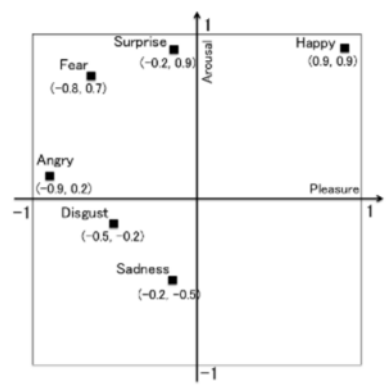


Fig. 3: Positions of emotional factors on 2D plane.

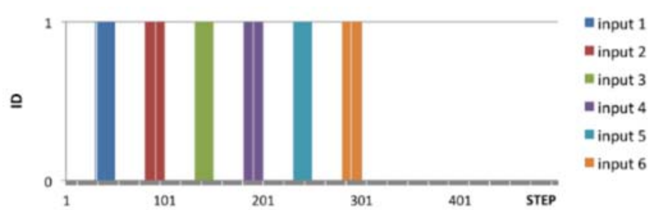


Fig. 4: History of the input data as multi-modal inputs.

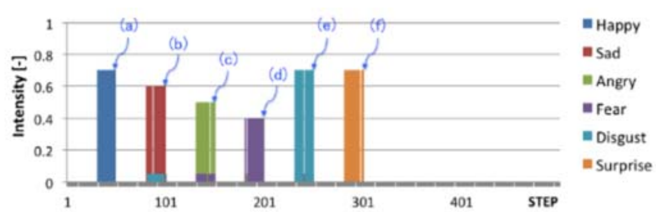
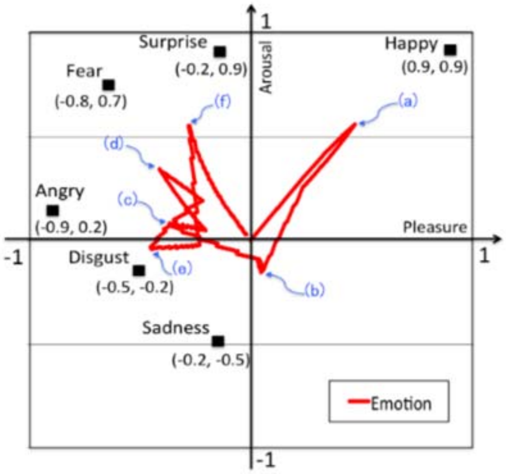
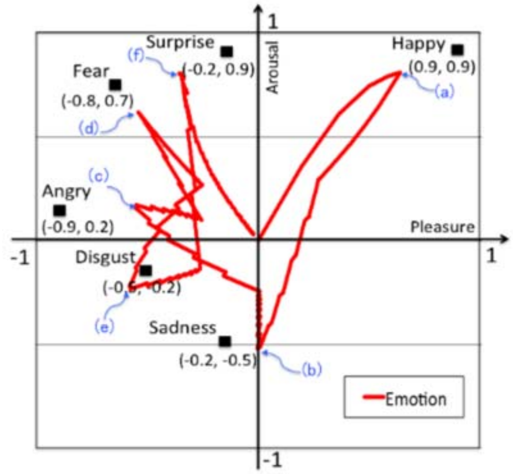


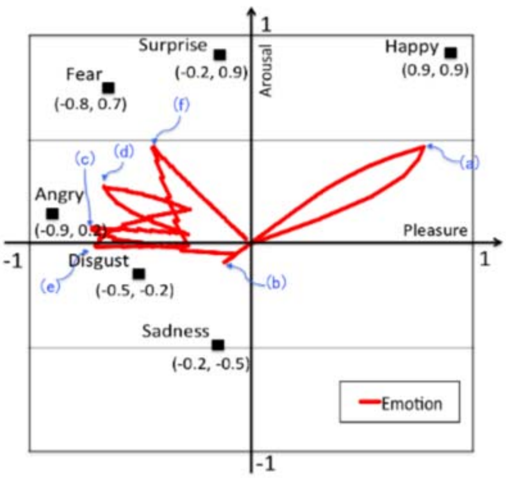
Fig. 5: History of the core affects based on multi-modal input.



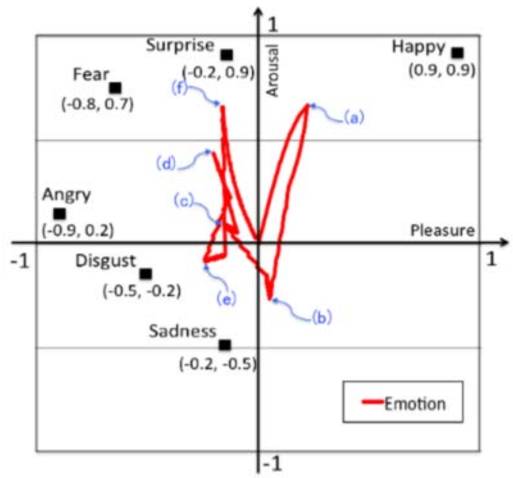
(a) Type 1 personality (O: 0.40, E: 0.30, A: 0.30, N: -0.20)



(b) Type 2 personality (O: 0.90, E: 0.70, A: 0.50, N: -0.60)

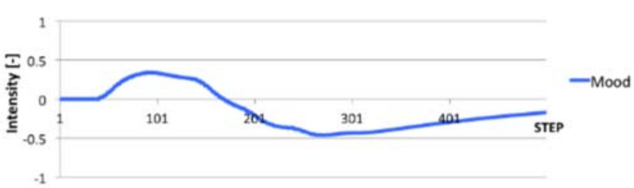


(c) Type 3 personality (O: 0.50, E: 0.10, A: 0.80, N: 0.20)

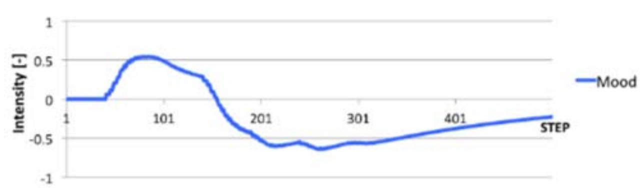


(d) Type 4 personality (O: 0.50, E: 0.20, A: 0.20, N: -0.40)

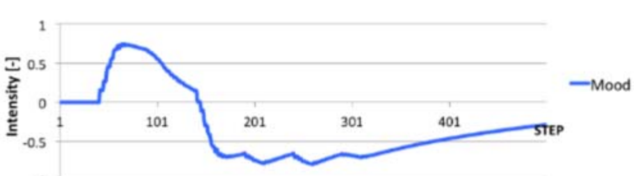
Fig. 6: Trajectory of emotion state with different personality factors.



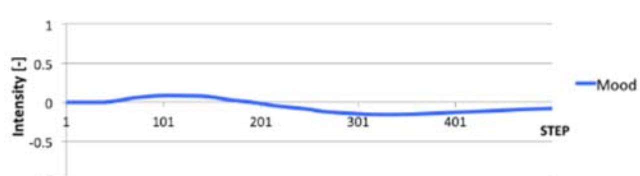
(a) Type 1 personality (O: 0.40, E: 0.30, A: 0.30, N: -0.20)



(b) Type 2 personality (O: 0.90, E: 0.70, A: 0.50, N: -0.60)



(c) Type 3 personality (O: 0.50, E: 0.10, A: 0.80, N: 0.20)



(d) Type 4 personality (O: 0.50, E: 0.20, A: 0.20, N: -0.40)

Fig. 7: Output of the mood state with different personality factors based on α-th axis of emotion state.

the emotional intensity from multi-modal information. In addition, we considered five factors of personality model called OCEAN model to represent the relationships between emotional factors and personality factors. From the simulation result, we can regarded that even if the same stimulus are given from the environment, the proposed model is able to generate the different emotional properties based on personality factors. Thus, if we apply the proposed emotional model to the communication robot, it is possible to define the unique communication robot with only changing the few personality factors. In addition, under the actual environment, the input information in Table II can be replaced to multi-modal information such as gesture, voice and facial expression. In other words, the proposed model is able to handle any types of information to generate the emotional information like humans.

As future works, we implement the proposed robotic emotional model to the communication robot, and develop the human-robot interaction system to confirm the further effectiveness of the proposed robotic emotional model under practical environment.

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