

## EMOTION EXPRESSION AND ENVIRONMENT THROUGH AFFECTIVE INTERACTION

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**Abstract:** This paper focuses on emotion expressions and environments through affective interaction between a human and a robot. To this end, we develop an emotion expression system includes an emotion engine, an experimental platform and a simulation tool. KOBIE is an experimental robot platform which provides emotional stability and continuous interest to a user through affective interaction. In addition, the simulation tool provides a visualization interface for the emotion engine and expresses emotion through an avatar. The proposed system can be used in the development of cyber characters that use emotions or in the development of an apparatus with emotion in a ubiquitous environment.

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### 1. INTRODUCTION

In the existing robot field, a main focus is on methods of generating emotion according to predefined conditions and expressing an action using simple external sensor information. In addition, research is being actively conducted to develop an intelligent robot that can interact with a user by detecting the emotional state of the user through an image taken by a camera and reflecting the detected emotional state via the creation of an emotion. However, such a conventional method, in which human emotion is detected by recognition of a human image or by recognition of the strength, tempo and/or tone of a human voice, has limited accuracy. A conventional emotion expression method mainly uses a human face, but emotion expression technology using other body parts remains insufficient.

AIBO (Fujita, 2000) of Sony is a pet-type robot that can control its natural actions in a manner similar to that of a living being so as to express emotions. AIBO calculates the intensity of desire or understanding based on information that is recognized through cognitive modeling, which is learned using external information including vision, speech, and tactile sensors. However, it is difficult to reflect the various emotions according to changing situations and environments.

WE-R4II (Waseda Eye No. 4 Refined II) is humanoid robot that was developed in order to implement new mechanisms and functions for a robot. It has the ability to communicate naturally with a human by expressing human-like emotion. This robot expresses emotions using face and body gestures. WE-4RII can express emotions such as "happiness," "anger," "disgust," "fear," "sadness," "surprise," and "neutrality" on the basis of the six emotions of Ekman (Ekman, et al., 1971). In addition, WE-R4II incorporates three-dimension mental space (WE-4RII; Hiroyasu, et al., 2003a; Hiroyasu, et al., 2003b).

The seal-like robot Paro was designed using a baby harp seal as a model. Its surface is covered with a type of fur. In this robot, ubiquitous surface tactile sensors are inserted between the hard inner skeleton and the fur to create a soft, natural feel and to permit the measurement of human contact with Paro. Paro is known as a mental commit robot. It provides mental values to its user, such as joy, happiness, and relaxation, through physical interaction (PARO; Wada, et al., 2006a; Wada, et al., 2006b).

MIT is conducting what it terms a Huggable project (Stiehl, et al., 2005). This refers to the installation of a sensitive skin on the entire body of an intelligent robot to provide a more natural interaction with a human being. Additionally, many researchers have investigated a multi-modal emotion recognition method that seeks to improve the performance and stability of recognition methods (Busso, et al., 2004; Sebe, et al., 2006).

In the present study, an emotion expression and environment through affective interaction between a human and a robot is described. The remainder of this paper is organized as follows. In Section 2, the emotion expression system architecture is presented. Section 3 describes the experimental robot platform and the environment. In Section 4, the paper is concluded and directions for future research are discussed.

### 2. THE EMOTION EXPRESSION SYSTEM

#### 2.1 Emotion Engine

The emotion expression system is comprised of an emotion feature collector component, an internal status management component, and an action expression component. The emotion expression system provides an interface in which the

emotional communication between a robot and a human being are possible.

Fig. 1 shows the architecture of the emotion engine. The emotion engine is the main component of the emotion expression system. The emotion engine is composed of an EFGM (Emotion Feature Generation Module), an ISGM (Internal Status Generation Module) and a BDM (Behavior Decision Module).

The EFGM generates factors that change the emotions of an emotional robot depending on the situation. In this paper, such a factor is referred to as an emotion feature. The EFGM consists of two parts, a stimulus process sub-module and a fusion sub-module, as shown in the Fig.1.

In order to generate emotion features from various sensors, the stimulus process sub-module is configured with independent stimulus processors.

A stimulus processor inserts sensor values in the form of numerical data into the emotion features, which are composed of nominal data. An emotion feature generated by a stimulus processor has the possibility of appearing in the current situation.

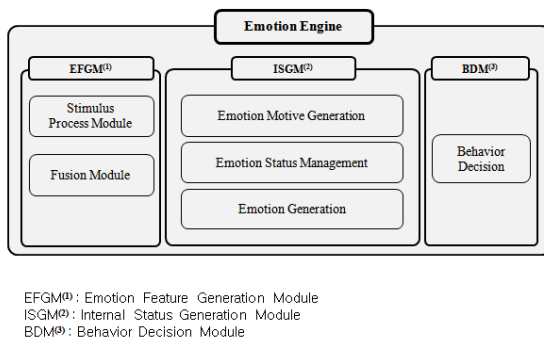


Fig.1 The architecture of the emotion engine

The stimulus processor can be designed using a symbolization method, a probability model, machine learning, and fuzzy logic. However, the processor time must be short. In this paper, in order to achieve more affective interaction between a human and a robot, a stimulus processor that generates the emotion features of 'stroke', 'tickle', and 'pat' was designed based on human touching behaviors from the method of the neural network proposed by (Ryu, et al. , 2007)

The fusion sub-module generates emotion features from the relationships among emotion features generated by the stimulus process sub-module. This sub-module is under development.

Emotion features generated by the EFGM are transferred to the ISGM in the form of the following equation:

$$EF_t = \{SP_i^t \mid 1 \leq i \leq n\}$$

$$SP_i^t = \{(e_{ij}^t, p_{ij}^t) \mid 1 \leq j \leq m_i\}$$

where  $EF_t$  is a set of generated emotion features at a certain time  $t$  and  $SP_i^t$  is a subset of  $EF_t$ . The emotion features generated by stimulus processor  $i$  are elements of the subset  $SP_i^t$ . The emotion feature is represented as the pair  $e_{ij}^t$  and  $p_{ij}^t$ . The element  $(e_{ij}^t, p_{ij}^t)$  represents the emotion feature  $j$  on stimulus processor  $i$ . In this element description,  $e_{ij}^t$  denotes a name of an emotion feature (such as 'tickle' or 'pat') and  $p_{ij}^t$  represents the possibility of this feature.  $n$  is the number of stimulus processors defined in the stimulus process sub-module. As the generated number of emotion features differs according to the stimulus processor, the number of emotion features generated by the stimulus processor  $i$  is defined as  $m_i$ .

The ISGM is the module that generates the internal status information using the emotion feature information. It is composed of three sub modules.

First, using the emotion feature information generated from a stimulus, the emotion motive generation module generates the emotion motives according to the changes of needs and the mood variables.

The emotion motive is affected by the results that change according to changes of the needs and mood parameters. The needs-parameter-based motives are generated in the priority order of physiological needs, safety needs, and love and belongingness needs. The mood-parameter-based motives are generated sequentially and repeatedly in a predetermined priority order. This is described in Sections 2.3 and 2.4 in detail.

Second, the emotion status management module manages information including the generation time of the emotion features, the occurrence of stimuli, the robot status information, the emotions, the emotion motive, and the behavior information. This module includes an emotion factor table for the storage of information and is illustrated in Section 2.6 in detail.

Third, the emotion generation module calculates the 3D emotion axis value using the emotion factor table information, maps the evaluation of the emotion axis value with the area of the emotion vector, and generates an emotion such as joy, surprise, fear, anger, shame, sadness or neutrality.

The BDM is the module that determines behavior in order to express an emotion. Each behavior determined for a single emotion can be comprised of a single elementary action of or by several actions. This module generates suitable behavior in the robot platform.

## 2.2 Needs Model

A needs model is based on Maslow's Hierarchy of Needs. The needs parameters are constituted by a five-step layer including physiological needs, safety needs, love and

belongingness needs, esteem needs, and self-actualization needs (Maslow, et al., 1943a; Maslow, et al., 1954b).

In this paper, the needs parameters are defined on the basis of physiological needs, safety needs, and love and belongingness needs. For example, needs parameters for physiological needs are hunger, sleep, hot, and fatigue.

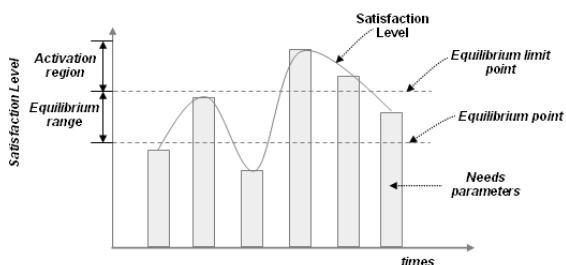


Fig.2 An example of needs-based emotion motive generation

Examples of needs parameters for safety needs are self-defense parameters for coping with conditions that are regarded as threat stimuli. Examples of the love and belongingness needs are curiosity for expressing interest for unusual items and people and loneliness that may arise when there is no change or stimulus during a predetermined time period. The emotion motive generator uses such parameters to generate emotional needs motives.

As shown in Fig.2, so that each of the needs parameters can maintain the equilibrium range of an emotion in the activation regions of an emotional needs motive, the emotion motive generator satisfies emotional needs motives while changing the satisfaction level through expression of emotions and emotional actions.

Table 1 shows the relationship of needs parameters and emotion features. For example, the emotion features of 'Near,' 'Head\_hit,' 'Back\_hit,' and 'Raise' are managed as a self-defense factor. In addition, an emotion feature affects multiple needs factors, as shown in Table 1.

**TABLE 1. The relationship of needs parameters and emotion features**

SelfDefense	Hunger	Sleep	Fatigue	BodyTemp	Hot	Loneliness	Curiosity
Near	Hunger	Dark	Hunger	InternalHot	Hot(Nose)	Quiet	Near
Head_hit	Time	Jaw_stroke	Time	InternalCold	Cold(Nose)	Time	Jaw_tickle
Back_hit		Jaw_tickle			Bright	Dark	Jaw_touch
Raise		jaw_touch					Head_stroke
		Head_stroke					Head_poke
		Head_tickle					Head_tickle
		Back_stroke					Head_touch
		Time					Back_stroke
							Back_tickle
							Back_poke
							Back_touch
							LSide_poke
							LSide_hold
							RSide_poke
							RSide_hold
							Sound

### 2.3 Mood Model

The mood model has six parameters that determine the change of moods through internal/external stimuli. The mood parameters are as follows: 'happy,' 'gloomy,' 'comfort,' 'irritable,' 'listless' and 'depressed'. The moods parameters affect the generation of emotional motives.

Table 2 shows the relationship of the mood parameters and emotion features. For example, the emotion features of 'Dark,' 'Dawn,' 'Head\_hit,' and 'Back\_hit' are managed as a 'Comfort' factor. In addition, an emotion feature affects multiple mood factors.

**TABLE 2. The relationship of the mood parameters and emotion features**

Happy	Gloomy	Comfort	Listless	Irritable	Depressed
Head_stroke	Dark	Dark	Dark	Head_hit	Bright
Head_tickle	Dawn_time	Jaw_stroke	Head_stroke	Back_hit	Near
Back_stroke	Head_hit	Jaw_tickle	Back_stroke	Back_poke	Head_hit
Back_tickle	Back_hit	jaw_touch		LSide_hold	Back_hit
Lside_tickle		Head_stroke		RSide_hold	LSide_poke
Lside_touch		Head_tickle		LHand_touch	LSide_hold
RSide_tickle		Back_stroke		LHand_hold	RSide_poke
RSide_touch				RHand_touch	RSide_hold
				RHand_hold	LHand_hold
				Raise	RHand_hold
				Noisy	

### 2.4 Emotion Factor Table

The emotion factor table is the main component of the emotion status management. It stores and manages the status information of robot that is generated by internal/external stimuli. In addition, the emotion factor table stores occurrences for internal/external stimuli, needs, mood, emotion motives, and emotions.

Table 3 shows an example of the emotion factor table. In addition, through the use of emotion factors, the emotion generator module generates emotions on the 3D emotion vector space.

**TABLE 3. An example of the emotion factor table**

Happy	Unhappy	Arousal	Asleep	Certainty
Happy	Gloomy	SelfDefense	Sleepiness	-
Comfort	Irritable	Hotness	Listless	-
Curiosity	Depressed	Hunger	Loneliness	-
Sleepiness	Hunger	Irritable	Gloomy(dark)	-
	Fatigue	Depressed	Comfort	-
	Loneliness	Gloomy(hit)	Fatigue	-
	Listless			

The emotion factor table contains the emotion factors of 'Happy,' 'Unhappy,' 'Arousal,' 'Asleep,' and 'Certainty', which are predefined. Needs parameters such as happy, comfort, curiosity and sleepiness are managed as features of the 'Happy' factor. Items such as gloomy, irritable, depressed, hunger, fatigue, loneliness and listless are managed as

'Unhappy' factors. The hunger, depressed, hot, and self-defense parameters are managed as 'Arousal' factors. Additionally, the sleepiness, listless, gloomy, comfort and fatigue parameters are managed as 'Asleep' factors. The information of the needs and mood parameters is pre-classified and used as emotion feature information for the determination of the 3D-emotion vector.

2.5 Emotion Model and Expression

The emotion model has two major models as OCC model and dimensional model. The OCC model (Ortony, et al., 1988; Arbib, et al., 1992) is based on interaction related emotion words, which are intuitively assigned from observation of human interaction. The representative model about the OCC model is the OZ project (Bates, 1994). But, The OCC model is difficult to express the continuous change about emotion values. On the other hand, the dimensional model (i.e. 2-dimension or 3-dimension model) can maintain the continuous change about emotion values.

The proposed system uses a three-dimensional model. The emotion model is implemented using Takanishi's model, which involves a vector space including "Pleasantness ( $E_p$ )," "Activation ( $E_a$ )," and "Certainty ( $E_c$ ).". Accordingly, a calculated emotion feature value corresponds to the vector  $E = (E_p, E_a, E_c)$ .

The emotion factor table, which is described in Section 2.6, outlines the 3D emotional axes.

The factors of 'Happy' and 'Unhappy' affect the "Pleasantness" axis, the factors of 'Arousal' and 'Asleep' affect the "Activation" axis, and the possibility of emotion features affect the "Certainty" axis. Fig. 3 shows the emotion vector space.

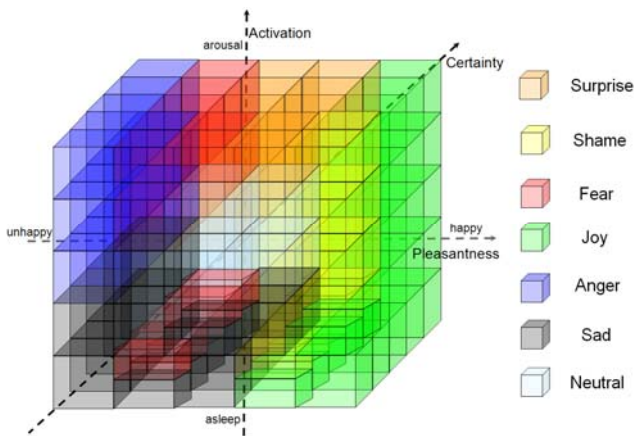


Fig.3 Emotion vector space

There are many ways of expressing emotions. The proposed system provides three emotion expression types: face, sound, and gestures.

3. THE EXPERIMENTAL ROBOT PLATFORM AND ENVIRONMENT

3.1 KOBIE (KOala roBot with Intelligent Emotion)

The appearance of the emotional robot KOBIE is shown Fig. 4. KOBIE is a human-friendly emotional robot with the shape of a koala. It provides emotional relief to a user through affective behaviors as well as human-activity monitoring through a low-cost vision system. The goal of KOBIE is to provide emotional relief and continued interest to a user through affective interaction. For this affective interaction, various sensors are used. Particularly, contact sensors (i.e., tactile and touch switch sensors) are used.



Fig.4 KOBIE

As shown in Table 4, KOBIE has 20-DOFs (Degrees of Freedom) and has a sensor, as outlined in Table 5. It can be express seven emotions (i.e., fear, surprise, joy, anger, sadness, shame, and neutrality) through its facial expression, sounds and body gestures.

TABLE 4. DOFs configuration of KOBIE

Part	DOF
Head	5 (Eyelid 1, Ear 2, Neck 2)
Back	1
Foreleg	8
Hind leg	6
Total	20

TABLE 5. Sensors on KOBIE

Part	Sensors
Head	Distance
	Visual (CMOS Camera)
	Tactile sensors
	PIR
	CDS
	Microphone
Back	Tactile sensor
Side	Tactile sensor
Legs	Touch Switches (on/off)
Paw	Touch Switches (on/off)
Hip	Touch Switches (on/off)



### 3.2 Emotion Expression through the KOBIE

Tactile and touch-switch sensors are used to detect touch behaviors including ‘hit,’ ‘stroke,’ ‘tickle,’ ‘poke,’ and ‘touch.’ Fig.5 shows the placement of the touch sensors that are attached to KOBIE. The tactile sensors are adhered onto the back (7), the head (4), the side (5), and the chin (4). The touch switches sensors are adhered to the legs (8), the paw (4) and the tail (1).

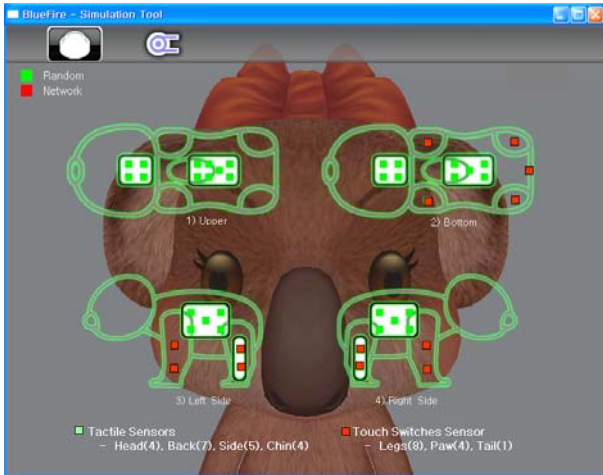


Fig.5 The placement of the touch sensors

KOBIE can sense the affective stimuli of tickle, stoke, hit, and poke. KOBIE diversifies emotions such as fear, surprise, joy, anger, sadness, shame and neutrality, and it can show various actions to a user. For example, if a user strokes its head or back, KOBIE will perform a cute trick.

### 3.3 Emotion Expression through an Avatar

A simulation tool that includes an avatar was developed for emotion simulation. This tool provides a visualization interface for the emotion engine and expresses an emotion through an avatar, as shown in Fig. 6 and Fig. 7.

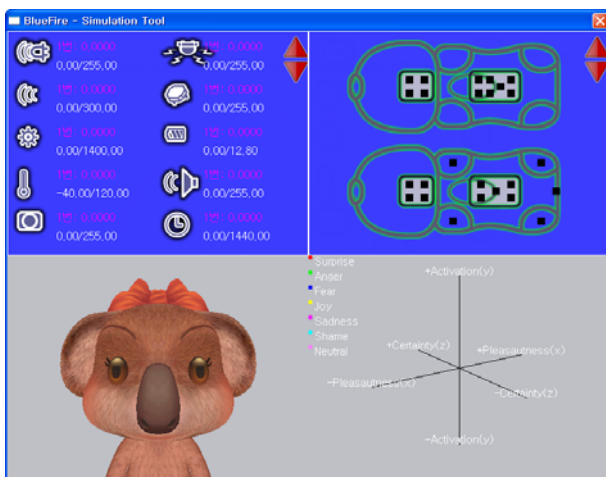


Fig.6 Simulation tool including an avatar

The simulation tool shows the emotion changes, sensor information analysis, emotion features information, emotion motives, and changes in a single emotions.

As shown in Fig. 7, according to the emotion and emotion intensity, it generates emotions (i.e., fear, surprise, joy, anger, sadness, shame, and neutrality) and expresses them through its avatar.

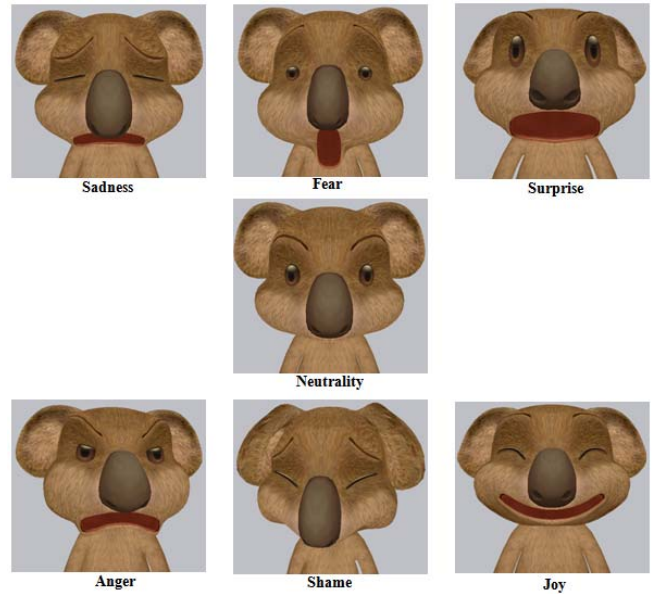


Fig.7 Emotion expression through an avatar

## 4. CONCLUSION

In this paper, the emotion expression and related environment through affective interactions between a human and a robot are described. We develop an emotion expression system includes an emotion engine, an experimental platform and a simulation tool. KOBIE is an emotional robot that was created to provide emotional relief and continuous interest to a user through affective interaction. Moreover, the simulation tool provides a visualization interface for the emotion engine and expresses emotions through an avatar.

The proposed system can be used in the development of cyber characters that use emotions or in the development of a pet-robot with emotion. In the future, we plan to add memory and a personality model to this platform.

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