Designing Emotional and Interactive Behaviors for an Entertainment Robot

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Abstract. In the process of developing an entertainment robot, Mon-e, we represented the robot's emotional and interactive behaviors in the form of scripts. A unified model was established to manage all the different scripts. We designed the personality profile to possess two dimensions of criteria for script selection. Emotion variable was introduced to create a variety of robot behavior according to the context. Reinforcing mechanisms of the personality profile and the emotion variable were developed.

Keywords: Human-Robot Interaction, Script-based Robot Behavior, Robot Personality, Robot Emotion, Service Robots.

1 Introduction

With the development of many types of personal service robots, researchers have been studying human-robot interactions. These studies have focused on the performance and safety of interfaces or actuators. However, it is also important to study how and when the many types of robot behaviors should be organized and presented to users. These issues can be resolved by analyses of tasks performed by robots and humans.

An entertainment robot, considered as a type of personal service robot, should behave like a human or in such a manner that users can predict it actions [1]. The actions of a robot must be understandable so that users can attribute its actions to rational causes. This proposition is related to another contention that holds that entertainment robots should have a diverse range of behaviors. When presented with a single stimulus, a human can react with several different expressive methods; hence, a robot can be expected to behave as a human. An entertainment robot should be able to present its own behavioral styles according to its individual personality in the manner similar to individuals behaving in different ways with each coherent trait.

In the process of developing an entertainment robot Mon-e (Fig. 3 shows its appearance), emotional or interactive behaviors were designed and they were applied to the robot by using several interfaces and actuators [2]. The appearance of the robot is similar to that of a monkey. It can move in every direction using three wheels and can

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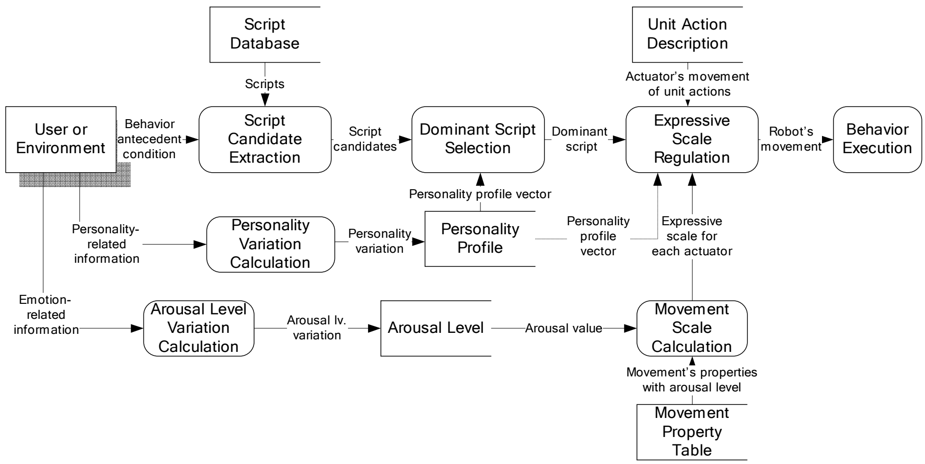

Fig. 1. Information flow diagram of the proposed system. The rounded rectangles, arrows, and rectangles with one side open represent primary processes, flows of information, and databases, respectively. The robot behavior management model is depicted at the upper part of this figure. The middle and lower parts show the variation process of personality profile and emotion state.

actuate its head and tail. Furthermore, it can change colors in some parts of its body and emit sounds through a speaker. The robot can recognize some noises, light, body heat, and touch and can measure its orientation on the basis of the principles of angular momentum. To diversify the interactive behaviors that utilize the abovementioned functions, several models developed on the basis of psychological studies on personality and emotion were established.

2 Robot Behavior Management Model

In order to realize robot behaviors, many robot planning and action selection skills have been introduced (the approaches are explained in [3]). The proposed model for the robot can not only show reactive behaviors according to specific situations but also exchange answers and questions with a user while maintaining the contextual knowledge of the actions. These interactive and reactive behaviors should be presented by using several styles according to the traits of the robot.

In this study, the scripts of robot behaviors are written and utilized in order to demonstrate the interactive behaviors [4]. In the scripts, the robot's behaviors are mapped to various situations, and many action procedures with their personality level are written for each behavior. By using such scripts, the behavior management model selects and executes the robot's response. This approach allows for the behaviors of the robot to become more reliable and allows the designer to modify or add behaviors easily.

The overall system configuration is depicted in figure 1. When an event that corresponds to the conditions described in a script database occurs, the system extracts the corresponding scripts, which are known as script-candidates. The script-candidates are evaluated on the basis of the personality profile and the script personality level.

Each script candidate is assigned a weight, and a script is eventually selected by means of a weighted random selection process. Before the execution of the script, the system determines the detailed scale and velocity of each action by referring to an emotion model.

3 Personality

Personality can be defined as the distinctive and characteristic patterns of thought, emotion, and behavior that define an individual's personal style of interaction with physical and social environments [5]. A robot's personality may provide useful affordance, providing users with a method to model and understand robot behavior [6]. Several researchers have emphasized that personality is a key factor in human-robot interactions [7,8]. Fong classified five common personality types used in social robots: Tool-like, Pet or creature, Cartoon, Artificial being, and Human-like [6]. However, even within a robot that has one of the personality types, there may exist various personality patterns; hence, we focus on finding dimensions that connote the various patterns. For further understanding of the personality, we must review personality researches on a human who is a user and model of a social robot.

3.1 Human Personality

Many approaches are adopted to explain human personality as several traits [9,10,11,12,13]. Cattell obtained sixteen personality factors by using questionnaires and factor analyses [9]. Eysenck introduced the PEN model [10], and Myer proposed the Myer-Brigg model [11]. However, many researchers agree that the five traits or dimensions provide an almost accurate description of human personality. Costa and McCrae's Five Factor Model [12] and Goldberg's Big-Five Model [13] adopt different methods for naming and interpretation; both the methods can be described by an abbreviated word: OCEAN [5].

- Openness (intelligent, imaginative, flexibility)
- Conscientiousness (helpful, hard-working)
- Extraversion-introversion (sociable, outgoing, confidence)
- Agreeableness (friendliness, nice, pleasant)
- Neuroticism (emotional stability, adjusted)

In particular, dimensions of extraversion and agreeableness are close to interpersonal traits [14] and are similar to two axes (dominance and friendliness) of interpersonal theory [15].

3.2 Robot Personality

Robotics researchers have defined personality on the basis of various concepts. These concepts can be roughly divided into the type-style of personality, as images specified by the user or developer, and the parameter-style of personality, as variables affecting robot behavior styles. Severinson-Eklund et al. regarded personality as a property that humans obtain from a robot's embodiment, motion, manner, and developed Cero character [16]. Edsinger et al., by using a similar definition of personality, attempted to realize a socially inviting personality by a robot's face [17]. Iida et al. set three cases of responsive behavior patterns for the robot's face, such as the follower and selfish types [18]. Yoon et al. presented personality types on the basis of emotion (anger, timid, enjoyable) and developed synthetic characters for each type [19].

Many approaches that employ the parameter-style of personality are based on the trait theory of human personality. Okuno et al. used personality to define the attention control of multi-talk by using the interpersonal theory [20]. Miwa et al. developed a human-like head robot and applied three dimensions of the five factor model [21]; they divided personality into sensing personality, which indicates how a stimulus works for the robot's emotion, and expression personality, which indicates how the emotion works for the robot's expression. While proposing a robot's framework (called as Tame), Moshkina and Arkin utilized all the dimensions of the five factor model to influence emotion, mood, and ultimately attitude [22]. Lee et al. used three dimension of the Big-five model as the tendency associated with motivation, homoeostasis, and emotion of artificial creatures [23]. For developing a robot for hands-off therapy, Tapus and Matataric considered personality as a key element that decides socially interactive behaviors [8]. They applied an extroversion-introversion level, one dimension of the Eysenck's Pen model.

For establishing the personality model, the established model should fulfill the following demands. Robot behaviors that originate from different personalities should be significantly realized and distinguished by the user. Furthermore, the model should be useful for the purpose of developing a robot. Variables of personality should be presented with consideration of the robot's expression capability.

Entertainment robots will be more affective if they can deliver diverse personalities according to user preference. Some researches have shown that a user's understanding about a robot's personality or behavior styles depends on the user's personality, gender, and age [8, 24]. Goetz and Kiesler revealed that user preference about robot personality relies on the purpose of robot applications [25].

When implementing OCEAN dimensions as the robot personality, it is not suitable to apply every dimension. Each difference within extraversion or agreeableness, which are interpersonal traits among OCEAN dimensions, is relatively easier to be distinguished by the user. However, the other three traits are difficult to be applied [20], and the difference in each trait may not be relatively useful for service robots. For example, a user who employs a robot that has a lazy and emotionally unstable personality may attribute the robot's behaviors to troubles of the system. Reeves and Nass insist that two principal factors responsible for the intermediate agent's personality are dominance and friendliness [26]. Hence, in this research, we assume that the developing robot is conscientious, emotionally stable, and intelligent and has many different levels of extraversion and agreeableness.

Two traits (extraversion and agreeableness) are applied to each robot's personality profile and scripts personality level. In the personality profile, there exist two variables, which range from –1 to 1. Each variable refers to a personality level of the robot (extraversion, agreeableness). In the script database, each script has a pair of personality levels. Each level receives one value among –1,0,1, indicating whether the content of each script is extravert, neutral, or introvert and disagreeable, neutral, or agreeable.

3.3 Personality Variation

Personality can be changed by accumulated experience. Thus, a personality variation process is instituted. The personality variation process allows for the robot behavior to change continuously. The robot personality profile can be changed on the basis of three factors (figure 2 depicts relationships between the three factors and vectors on a coordinates). The first factor is termed "inherent disposition." The inherent disposition refers to the tendency to become a particular personality profile independently of the user input or situational issues. The second factor is termed "manual setting." The user can select the robot's personality through a control panel. The last factor is the reinforcement from the robot's incoming information. For example, rude user behaviors such as shaking or overthrowing the robot can cause the robot to become disagreeable. Additionally, some attentive user actions such as hugs make the robot agreeable. Related rules and equations are developed for this process.

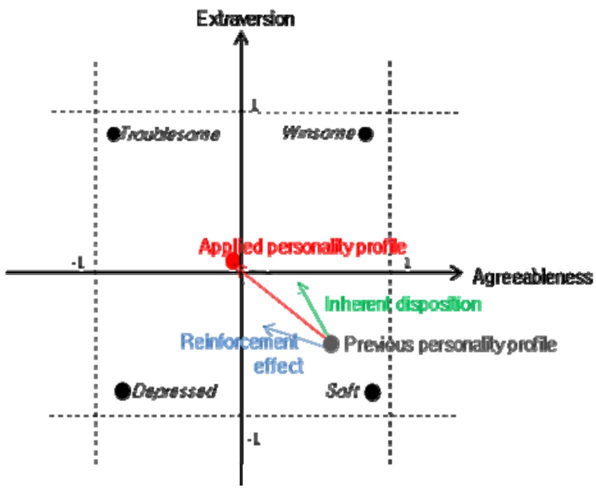

Fig. 2. The personality profile can be represented as a vector on a two-dimensional plane. The personality is changed by manual settings (one of the four points such as winsome, soft, etc.), reinforcement effect, and inherent disposition.

4 Emotion

Most interactions between entertainment robots and users are emotional interactions. A robot's reactions are related to simulating how the robot feels during a recognized situation. Hence, social robots require the capability of expressing and inducing emotions to interact with users plausibly and reliably [27]. Because a script-based behavior model is used, a pre-scripted database contains data indicating how the robot reacts to situations or human emotions. The robot does not interpret situations or understand human emotions autonomously, but it shows emotional interactions by following the contents of an appropriate script. Abundant script-databases and personality profiles allow diverse emotional interaction.

The script-based behavior model has some limits. The model cannot diversify behavior in conformity to a robot's emotion state. Emotions are continuously affected by the lapse of time as well as particular events, although, in this approach, a robot's emotional behavior discretely changes with some events represented in scripts. To overcome these problems, this paper presents an emotional parameter which varies robot behaviors according to time and events.

4.1 Arousal Variable

In spite of brisk researches on emotion, there still exist many arguments on how emotions arise and how emotions are classified [28]. There are three major hypotheses to classifying emotions. The first hypothesis is that emotion can be categorized by some basic emotion [29]. In this approach, changes in emotion can be described by some production rules. The second approach, called as component process theory, denies the existence of basic emotion and argues that emotions consist of underlying, more elementary units [30]. The final approach describes emotions not by listing them separately but as points along some small number of continuous dimensions [31]. This approach presents conceptual dimensions that explain the relationship among emotions, and it reflects compound emotions as well as basic emotions. We come up with the final approach to apply continuous emotional variables.

As one of the dimensional approaches, Russell proposed a circumplex model with two dimensional variables [31]. Watson and Tellegan proposed two axes of positive affect and negative affect [32], and Smith and Scott proposed a three-dimensional space of pleasure-displeasure, attentional activity, and personal agency/control [33]. Breazeal developed an emotion robot to express emotion by dimensions of arousal, stance, and valence [34]. Many researchers have mentioned attention or arousal dimension and pleasure-displeasure or valence dimension as principal dimensions.

Arousal and valence have different causes for change in their values. Emotion variations in valence dimensions range from happy or pleased to annoyed or frustrated, and the main factor of the variance is cognitive appraisal about particular situations. Breazeal states that valence is associated with how much the stimulus is relevant and pleasant intrinsically and how much the stimulus is directed to the robot's goal. It does not appear easy to quantify the appraisal of valence. Therefore, in the robot behavior management model, valence-related information of a robot's expression is included in the contents of the script database.

On the other hand, arousal variables can take emotion values ranging from exited or astonished to tired or sleepy. Arousal variables depend on lapse of time. Furthermore the arousal state evoked from an irrelevant event affects interpretation of events that are emotionally both positive and negative [35,36]. One of the examples is that men on a wobbly bridge feel more attractive to a female interviewer as compared to men on a sturdy bridge. This result implies that an arousal state can have an effect on further emotional states, whatever the cause of the arousal. On the basis of the above results, arousal is a useful variable for the behavior management model.

4.2 Variation of Arousal Value and Its Function

Breazeal proposed effective appraisals as intensity of stimulus, relevance of stimulus, intrinsic pleasantness, and goal directness, and he stated that arousal was related to intensity and relevance [34]. We added the activity level of robot movement as the cause of arousal.

- Intensity of stimulus: strong stimulus increases the arousal level (e.g., loudness of sound and intensity of light or user's touch)
- Relevance of stimulus: specific stimulus increases or decreases the arousal level (e.g., confrontation of an obstacle, user's calling, and robot's falling down)
- Robot's movement: a large number of movement increases the arousal level (e.g., actuating tail, head, or body)

These factors vary the arousal level according to a related rule, and the level is deactivated as time passes. The decay process follows an exponential function.

$$\mathrm{Arousal}_t = (\mathrm{Arousal}_{t-1} + \mathrm{Arousal}_{event}) \times k^{t_{event}} \quad (1),$$

where k denotes the decay constant; t, the current time; t_event, the time passed from stimulus; Arousal_t, the current arousal value; and Arousal_event, the value added due to the three factors. The Arousal value ranges from positive to negative and determines the range and velocity of movements about the action being executed. Examples are shown in table 1.

Table 1. The scale of each actuator moves according to the arousal value. When the arousal value has a number that lies between the columns of this table, the scale is calculated by using a proportional expression.

Part		*Arousal: 0*	*Arousal: 1*	*Arousal:-1*
Head	-Angle range	0°~15°	0°~20°	0°~12°
	-Velocity	2 cm/s(100%)	2.5 cm/s(150%)	1 cm/s(50%)
Color remaining period		0.5 s(100%)	0.3 s(80%)	1 s(200%)
Moving velocity		10 cm/s(100%)	15 cm/s(150%)	5 cm/s(50%)
Tail	-Angle range	0°~30°	0°~45°	0°~15°
	-Velocity	30°/s(100%)	60°/s(200%)	6°/s(20%)

5 Implementation

The proposed models and established variables were implemented onto a 3D graphic simulator and onto the Mon-e robot platform (the snap shot is shown in figure 3). The 3D graphic simulator was developed for efficiently examining the diversity and understandability of behaviors evoked from the behavior management model.

We wrote many different scripts by using a script exploration method [37]. When the simulators perceived a particular environment, the behavior management model selected a proper dominant script according to values of extraversion and agreeableness. For example, when a user turns on the robot having a winsome personality, it sings songs and dances. When the user turns on the robot having a depressed

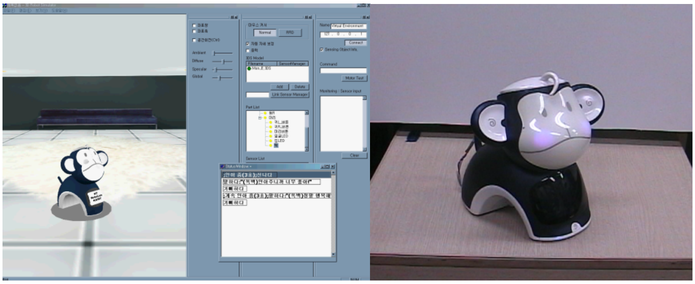

Fig. 3. The 3D graphic simulator (*left*) and Mon-e robot platform (*right*)

personality, it just displays a starting screen. After selecting the dominant script, the management model determines the velocity and scale of each motion in line with the arousal level, and it then sends motion commands to an execution module. As some situations were inputted to a simulator or robot platform, the arousal level or personality profile was varied by a few degrees.

6 Conclusion

In this paper, to demonstrate emotional and interactive behaviors of a robot, we proposed several models and variables. We investigated psychological researches and robotic results associated with personality and emotion. The established models were implemented on to a graphic simulator and Mon-e robot platform. As part of future studies, using several types of user test, we will validate and improve the practical effects of the proposed system.

Existing researches on the robot's emotional behaviors have focused on how to make the robot's behavior human-like or animal-like so that the robot's behaviors can be modeled on the basis of motivational factors such emotion, drives, or homeostasis [38,34,23]. We introduced an approach to show diverse behaviors on a robot's personality in order to create affective services or behaviors of entertainment robots. The behavior management model that uses scripts is effective to manage highly complex interaction procedures. For example, when a user turns on a robot, the robot can ask some recommendable services, obtain the user's response, and execute a service in accordance with the user's response. Several scripts in the model allow the robot to react to several responses. The behavior management model has an advantage that designers or users can easily modify and add scripts. If a system to support writing scripts is developed, the modification will be more enhanced.

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