Implementation of an Emotional Virtual Creature with a Growth Function Model

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Abstract. In this study, we developed an emotional virtual creature that grows according to a growth function model influenced by user input. Our preceding study proposed a growth model for emotions based on changes in the network structure of a self-organizing map. We applied a multilayer perceptron neural network to generate more sophisticated emotional expressions using growth functions. This model generated behavior similar to affective change, as described in behavioral genetics. Based on the growth model for emotions, we propose a virtual creature with which a user can interact using a tablet computer. This creature resembles a bouncing ball and changes color depending on its emotion. The user can pet or tap the creature, play with it using some items, and provide it food. The creature's actions and emotional expressions are influenced by a various stimuli from the user. We implemented the virtual creature using an Apple iPad and confirmed that the creature grew and learned various emotional expressions through user interaction.

Keywords: Entertainment robot, Emotional model, Tablet computer.

1 Introduction

Recent technological advances have expanded the market for entertainment robots with artificial intelligence (AI). As a result, many models for robot emotions have been proposed [1]–[5]. Several emotional models for artificial neural networks (ANN) have been developed. The models focus on emotional recognition, control, and expression. Generally, these emotional models use a simplified emotion- generation algorithm, and users quickly lose interest in simple systems. Although some models have attempted to generate more complex expressions, no previous studies have considered the growth of a robot.

Our preceding study proposed a growth model for emotions that focuses on two approaches [2]. The first approach increases the emotions as robots grow using a self-organizing map (SOM) [6], which is a type of ANN. SOMs are used for data mining, clustering, and pattern recognition. A SOM is a single-layered ANN that uses an algorithm for competitive learning, which does not require a teaching signal. Based on this structure, the model can classify an input that has not been learned. The network learns unknown external stimuli continually and classifies similar input (emotions) even if an input is unknown.

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The second approach changes time-series of emotion in a network's behavior using a working memory system. An emotion is affected by previous emotional conditions. Therefore, creatures remember previous emotional conditions for a specific period. Our growth model for emotions uses a multilayer perceptron (MLP) ANN to implement the changes in expressiveness and the development of emotions affected by previous emotional conditions.

Our previous study indicated that this emotion model was more suitable for producing a robot with growth functions based on a psychological model using numerical simulations. However, we did not develop any actual robots or applications using this model.

Based on our growth model for emotions, we propose a virtual creature that can communicate with users by means of tablet computers. We implemented our emotional growth model for robots in an iPad application.

2 Emotion Growth Model

In this model, we propose a robot that can communicate with users through an "emotion" function. Many emotional models handle emotions from a psychological perspective [7]; therefore, we discuss emotional development from this perspective. Our emotion model is based on genetic psychology and the concept of working memory [8].

Figure 1 illustrates the structure of the emotional growth model in [2]. We built the model based on two ideas. First, we attempted to identify similar emotions and to increase the number of emotions that can be expressed. Our model uses a SOM and an ANN. With the SOM structure, the network repeatedly learns new data and classifies similar emotions for each input. In addition, to increase the number of types of emotion that can be expressed, we changed

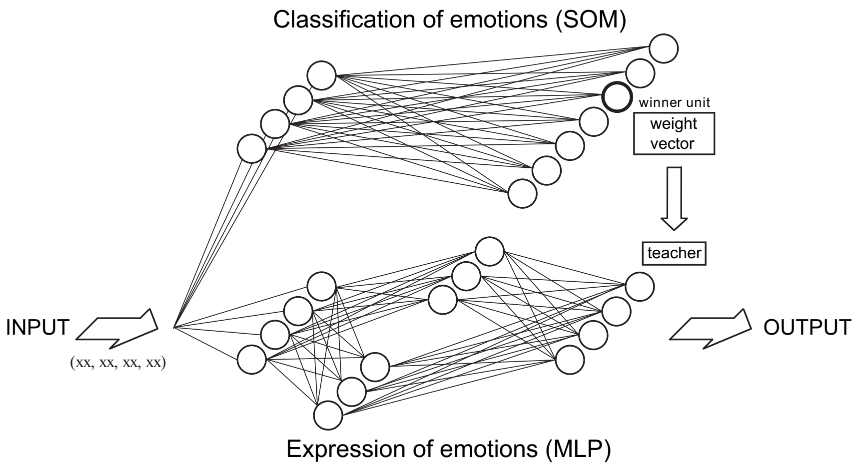

Fig. 1. Structure of the Emotional Growth Model

the number of connections between the neurons that constitute the SOM. The output units express emotions. The number of additional emotions that can be expressed as output is determined by the number of units. This structure enables the model to develop more complex emotions, which we refer to as "the evolution of network." In addition, to depict the stages of emotional development, we define a simplified version of the emotion differentiation model proposed by Bridges [9]. We call the branching structure of this emotion model the "emotion tree."

Develop realistic emotions using only an SOM network is difficult because the emotions that actual creatures develop are influenced by previous emotions, but SOM networks are not influenced by time-series inputs. Therefore, we used a multilayer perceptron (MLP) ANN to model the influence of previous emotional states on emotional changes, and the resulting model can generate complex emotions. We consider this to be a model of short-term "working memory." Using the MLP structure, the network can express emotions that have been affected by previous emotions. By combining the two networks described above, we have built a model that generates more realistic emotions for robots.

3 Application

We have implemented a virtual creature with the emotional growth model described above in an iPad application. This virtual creature (character) has an emotional growth model with two inputs and two outputs. These inputs depict the character's internal states, such as pleasure and arousal, which are two axes of the circumflex model of affect proposed by Russell [10]. The coordinate value of the outputs in the circumflex model presents the character's current

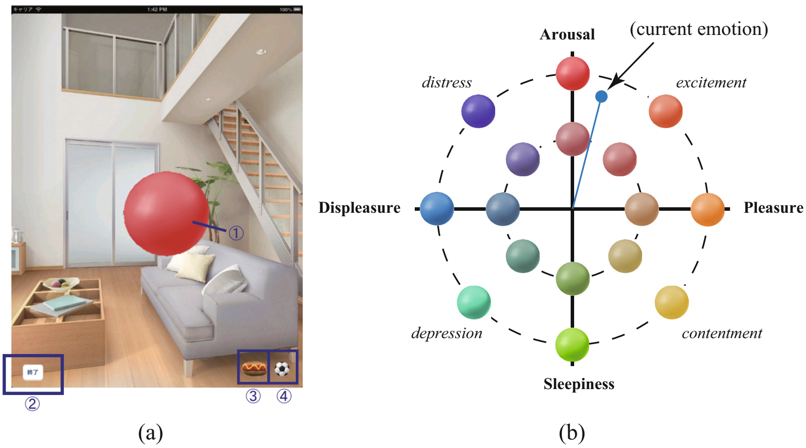

Fig. 2. Application of Virtual Creature with the Emotional Growth Model

emotional expression towards the user. In addition, the character has two physiological desires–appetite and sleep drive. These two desires strengthen with time and are reduced when satisfied. The two desires affect and change the degrees of pleasure and arousal. As the character's appetite is satisfied by eating food, the degree of pleasure increases and arousal slowly decreases. Then, the sleep drive gets stronger, because the character wants to sleep on a full stomach; its sleep drive is reduced by sleeping.

Figure 2 presents the GUI of the application and the correspondence between the character's emotions and colors. The object in Figure 2(a) that is marked (1) and resembles a ball is the character. It can move around the screen slowly or quickly. The button (2) is for quitting the application. Icon (3) represents food and icon (4) represents a ball. Users interact with the character by touching the screen. If they want to provide it some food, they drag and drop the food icon (3) anywhere on the screen. To play with it character, they drag and drop the ball icon (4). If the character is satisfied, it moves to catch the ball. When the users play with the character for long, the character's pleasure increases but its arousal slowly decreases owing to fatigue. Its desire for both food and sleep grows stronger. In contrast, leaving the character alone for a long time makes it disappointed and its pleasure decreases slowly. In addition, its pleasure also decreases when its sleep is disturbed.

The character expresses its emotions through simple colors and action patterns. It always expresses emotion within a range marked by eight cardinal emotions: arousal, excitement, pleasure, contentment, sleepiness, depression, displeasure, and distress. These emotions are arranged on the circumflex model of affect hues illustrated in Fig.2(b). Each emotion has a single hue, within which there is a gradient of intensity. When the creature's emotion is strong, its color is more vivid. The hue and intensity of the color of the creature are selected according to the output values of the MLP NN.

The size of the character changes slightly and constantly in simulation of breathing. This movement is faster when it is aroused and pleased, and slower when it is sleepy and displeased.

At the beginning of user interaction with the character, it expresses only simple emotions, because only a few neurons are connected in the SOM network. The number of types of emotion increases as more neurons are connected and it gains experience interacting with users. Through these features, the application allows users to interact with the character as they do with real creatures, in an interaction in which users act like pet owners.

4 Experiment

We experimented with the application using an Apple iPad. We gave 29 college subjects two types of applications and asked them to answer a questionnaire about their impressions of the characters. One of the applications had an inexperienced character that expressed only simple emotions when first interacting with users. The other application had an experienced character that had an

SOM classifying internal states into eight emotions and a learning ANN. The two versions of the characters were visually indistinguishable.

The questionnaire survey showed that several subjects realized that the inexperienced character was growing and beginning to express a variety of emotions during interaction. Some subjects answered that they felt the inexperienced character seemed abandoned, carefree, or insubordinate. In contrast, they considered the experienced character simple and amenable.

In the experiment, subjects interacted with the two characters without time restriction. The operational log shows that almost all subjects interacted with the inexperienced character longer and more often than the experienced character. This result indicates that an unfledged and primitive creature attracts users strongly.

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