Evolutionary Simulations based on a Robotic Approach to Emotion

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Abstract

This paper reports on the current state of our efforts to synthesize emotion in robots from a selectionist perspective in order to explore the origin and the adaptations of emotion and to realize efficient robotic systems. We have defined a minimal model of emotion in robots based on a behavioristic theory on human emotions, and have shown by conducting a robotic experiment that human beings can identify a set of basic emotions in robots. In this paper, we conduct evolutionary simulations based on the definition of emotions to verify the evolutionary adaptivity with the scenario of the origin and the evolution of human emotions in mind. The simulations show that robots are evolved to move effectively in the environments with various physical conditions by changing their emotions corresponding to the type of the condition they encounter.

Keywords: Emotion in robots, Artificial life, Behavior modulation, Evolutionary psychology

1 Introduction

The function of emotion has been studied by many researchers. Typical explanations are based on flexibility of behavior response to reinforcing signals, communications which transmit the internal states, or social bonding between individuals, which could increase fitness in the context of evolution. We believe that the possession of emotion is an adaptive "trait" also to robots, which is parallel with a selectionist view that emotion in humans is the product of adaptive evolution. The first purpose of our study is to explore the origin and the adaptations of emotion by synthesizing an emotion system "as it could be" in robots (Fig. 1). The second purpose is to realize an efficient robotic system in which robots perform tasks flexibly and effectively by using their emotional system. Although there is a possibility that our emotion system is rapidly becoming obsolete as our life environment has changed at a much faster rate than evolution, the emotion system in robots can be optimized according to given tasks by evolutionary algorithms.

We have already proposed a minimal model of emotion in robots, which is based on Dietrich Doerner's theory on human emotions described in Section 2. Also, we have shown by conducting a robotic experiment with 1000 human subjects that human beings can identify a set of basic emotions in robots synthesized based on the definition [1].

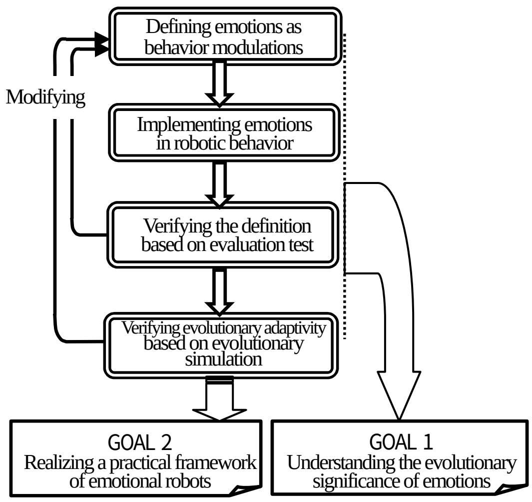

Fig. 1 Study scheme.

Based on these, this paper conducts evolutionary simulations to verify the evolutionary adaptivity with the scenario of the origin and the evolution of human emotions in mind. Each robot moves with the emotion based on 4 modulator values (activation, externality, precision and focus) from the start point to the goal point in the environments with various physical conditions like hazard, poorly-lit and so on. The fitness function is defined as the time for completing the task. In the first experiments, each individual contains modulator values directly in its genome, and is evolved in an environment with one type of conditions. In the next experiments, each robot has a simple neural network in which input is the type of conditions of the area and output is modulator values. Each individual contains the synaptic weights. Robots are evolved to move effectively by changing their emotions corresponding to the type of the area they encounter in the environment.

2 Emotions as Behavior Modulations

Our model of emotion in robots is based on the Dietrich Doerner's theory on human emotions. His claim is, in short, that emotions are seen as behavior modulations [2][3][4]. The theory identifies four different modulators that describe goal-directed behavior at any given time, activation, externality, precision and focus.

a) **Activation** indicates the amount of nonspecific activation that is involved while pursuing a goal. It has the extremes of hypoactivation (a lack of energy) and hyperactivation (a surplus of energy).

b) **Externality** indicates the proportion of time spent in external activity. It has the extremes of introversion (devoted mainly to information processing) and extroversion (devoted mainly to action).

c) **Precision** indicates how much care or precision a goal is pursued with. it has the extremes of imprecision and precision.

d) **Focus** indicates the amount of attention that is allocated to the current task rather than to the surveillance of the background. It has the extremes of broadened senses and of narrowed senses.

Following analogy [5] might help our understanding of emotions as behavior modulations. For example, a television can be adjusted for brightness, contrast and so on. These adjustments determine a "behavior modulation" for the television such as how bright, how much contrast and so on. The point here is they are all independent of the TV program actually showing. Similarly, human behavior can be modulated by emotions as behavior modulations. The volume control and so on in televisions correspond to activation, externality, precision, and focus in the emotion systems. Fig.2 shows a simple overview of this concept. Emotion system modulates behavior selected by another system (behavior generator). Each modulation pattern is associated with a particular emotion as shown in Tab. 1.

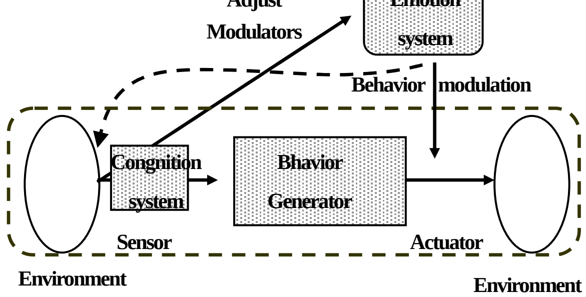

Fig. 2 An overview of the concept of behavior modulations.

We have defined following four modulators to synthesize emotional behaviors in the robot used in the simulations.

Tab. 1 Modulation patterns of six emotions [4].

	Modulation pattern in terms of modulators			
Emotion	Activation	Externality	Precision	Focus
None	0.50	0.50	0.50	0.50
Anger	1.00	1.00	0.00	1.00
Anxiety	1.00	0.00	1.00	1.00
Contentment	0.25	0.25	0.75	0.00
Excitement	0.75	0.75	0.25	0.00
Sadness	0.00	0.00	1.00	1.00

a) **Activation** indicates how long each behavior cycle is. The robot uses a certain amount of energy to move in one behavior cycle, which also depends on this modulator value.

b) **Externality** indicates how fast it moves through the path.

c) **Precision** indicates how far its sensory range to obstacles is and how often it updates the sensory information.

d) **Focus** indicates how often it deviates from the route. If it concentrates on its task, it moves to the goal directly along the route (the dashed line in Fig.4). If not, it deviates from the route. It also indicates how far its sensory range to light resources and the goal is.

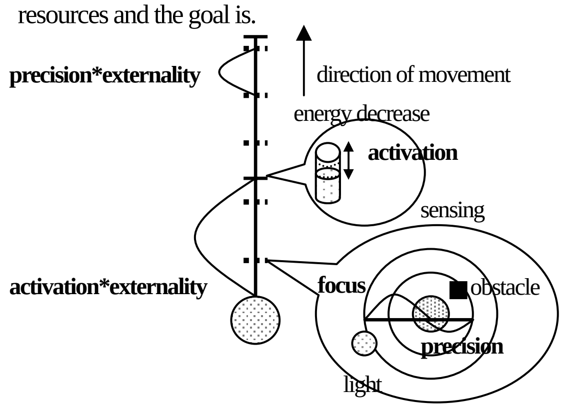

Fig. 3 Modulations of the robot behavior.

3 Evolutionary Simulations

3.1 Environmental setting

We conducted evolutionary simulations based on our definition of emotions so as to verify the evolutionary adaptivity. In the simulations, a robot moved "emotionally" from the start point to the goal point in the environments with various physical conditions [1](Fig. 4) including a hazard area (Zone A) where the robot suffers serious damage every second, a narrow path (Zone B) where it is difficult for the overly cautious robot to move through, a poorly-lighted area (Zone C) where the visual range of the robot is limited, and a light-rich area (Zone D) where the robot can fill in its energy if it finds a light source.

1 Plain area without any particular physical conditions is also in the environment.

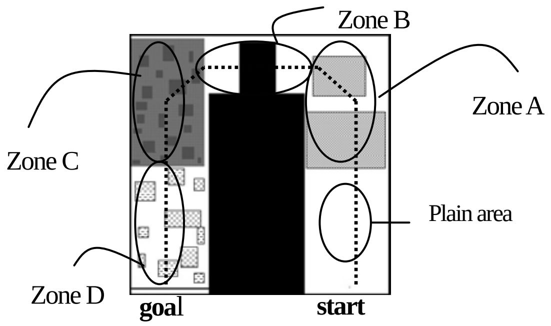

Fig. 4 An environment with various physical conditions.

3.2 Experiments with a single type of zones

Each individual contained 4 modulator values directly in its genome, and was evolved in an environment with one type of conditions by a genetic algorithm. The fitness function was defined as the level of the energy when the robot completed the task. Fig. 5-9 shows the result of the experiments. It is shown that particular modulation patterns representing the typical emotions emerged corresponding to the given environments. For example, the individuals with the anger-like modulation pattern were adaptive in the environment with a hazard area. Also, it is shown that expression of sadness and excitement in action was adaptive in the environment with poorly-lit and light-rich area respectively. Environments with a narrow path evolved the individuals expressing somewhat angry behavior.

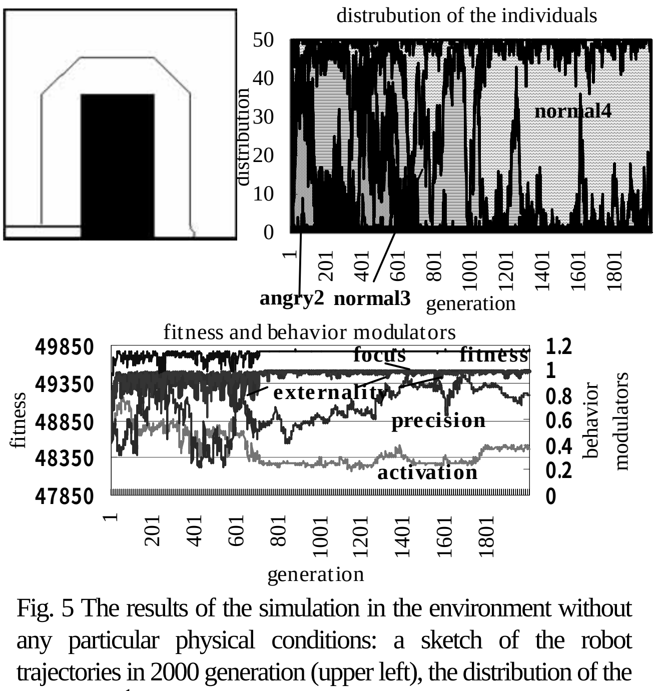

Fig. 5 The results of the simulation in the environment without any particular physical conditions: a sketch of the robot trajectories in 2000 generation (upper left), the distribution of the individuals[1] (upper right), and the average fitness and the behavior modulators of 50 individuals (lower).

[1] Hamming distance between four modulators of individuals and modulation patterns of six emotions (Tab. 1) are used to classify the emotion of individuals. The smaller the suffix number is, the closer to the basic six emotions.

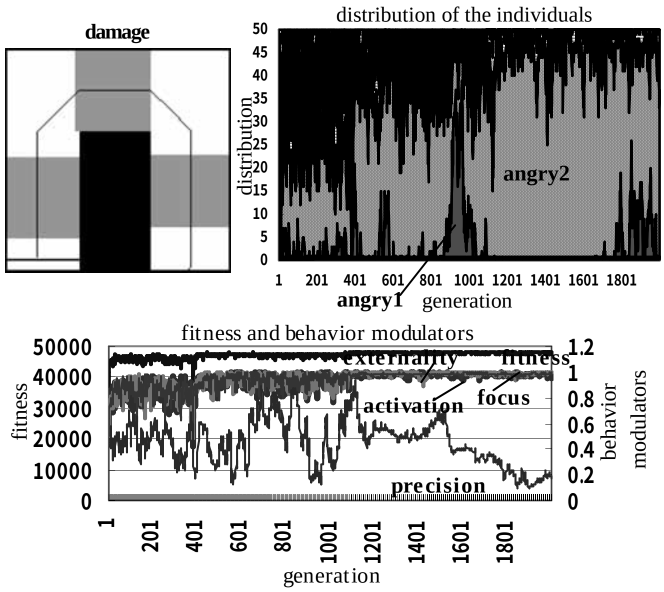

Fig. 6 The results of the simulation in a hazard area.

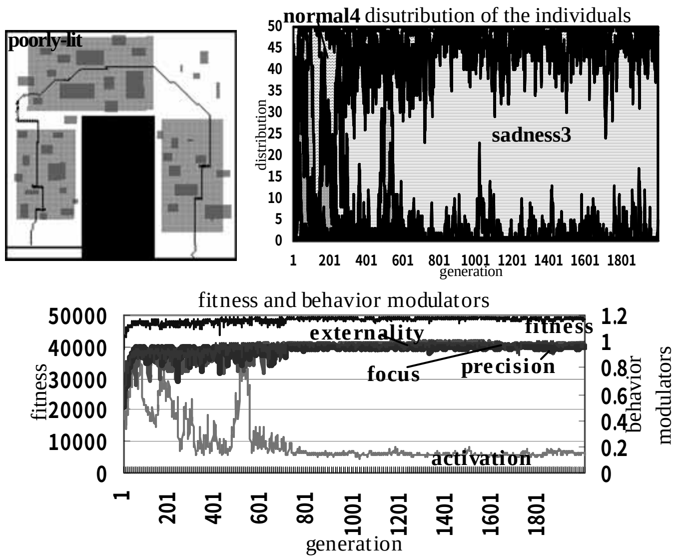

Fig. 7 The results of the simulation in a poorly-lit area.

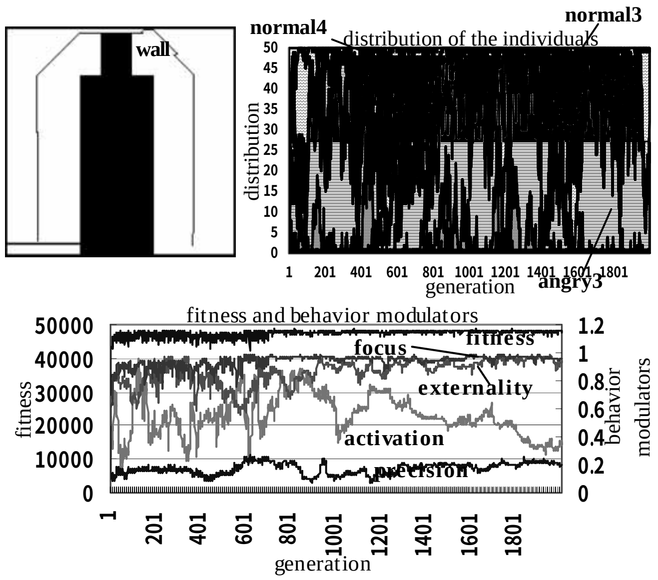

Fig. 8 The results of the simulation in the environments with a narrow path.

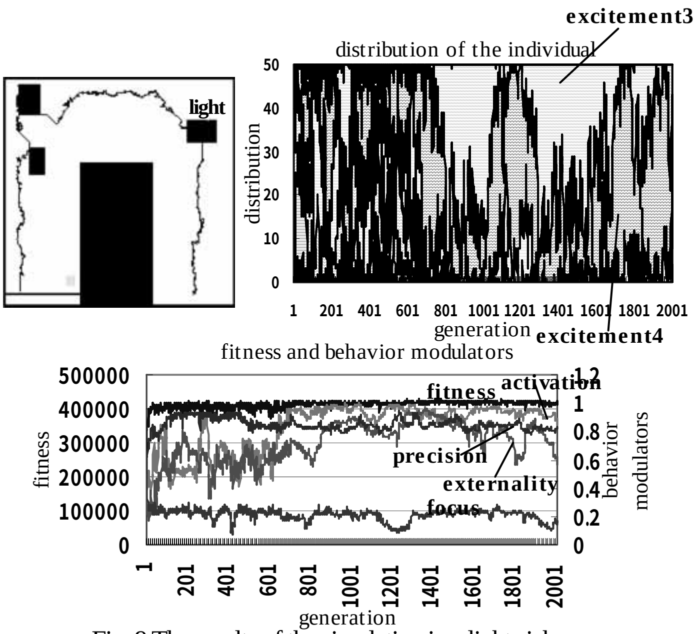

Fig. 9 The results of the simulation in a light-rich area.

3.3 Experiments with mixed types of zones

In the next experiment, the robot has a simple three-layer neural network (three input neuron, five hidden neurons and four output neurons), in which input was the explicitly expressed type of conditions of the area and the output was the modulator values. Each individual contained the synaptic weights, and evolved to move in the environment shown in Fig. 4 effectively by changing their emotions corresponding to the type of the area they were in. We also conducted another experiment using the same environment but evolving directly four modulator values as shown in 3.2 to evaluate and compare the results.

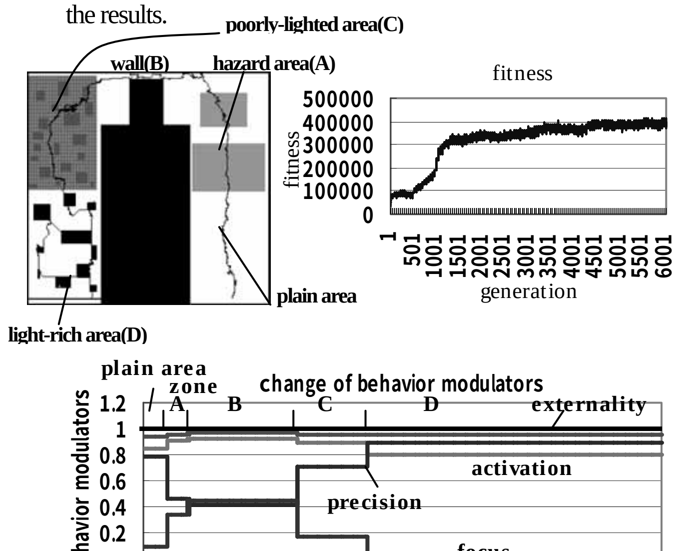

Fig. 10 The results of simulation in the environment with mixed types of physical conditions: a sketch of the robot trajectories in generation 6000 (upper left), the average fitness of 50 individuals (upper right), the change of the behavior modulators corresponding their location in generation 6000 (lower).

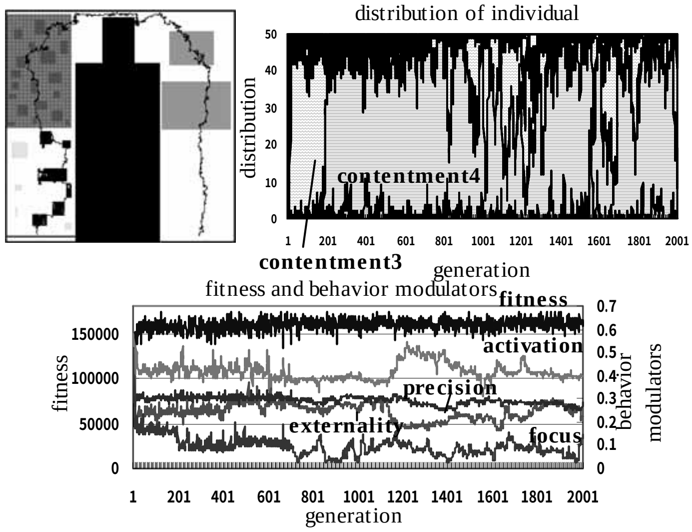

Fig.11 The results of simulation in the environment with mixed types of zones in the same setting as in 3.2.

The results of both experiments are shown in Fig. 10 and Fig. 11 respectively. We see from Fig. 10 that the robot was evolved to adjust its behavior modulators properly corresponding to the type of the area where it moved. The fitness of the robot with the evolved neural network in the last generation was $4.46*10^4$ and the fitness of the robot with evolved fixed modulator values in the last generation was $1.74*10^4$, which clearly shows the effectiveness of the robot behavior with dynamically changing its emotion corresponding to the environmental change.

4 Conclusion

We have conducted evolutionary simulations based on the definition of emotions in robots and have shown that particular modulation patterns representing the typical emotions emerged corresponding to the particular physical conditions. It has also been shown that the robot with a simple neural network moved effectively by changing their emotions corresponding to the environmental change. These results show that possession of emotion is adaptive for robots, which is parallel with a selectionist view that emotion in humans is the product of adaptive evolution. We are now conducting more practical evolutionary simulations in which robots change their emotions according to their actual sensor values and their internal states.

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