A Robotic Approach to Emotion from a Selectionist Perspective

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Abstract

This paper reports on the current state of our efforts to synthesize emotion in robots from a selectionist perspective. As a first step, we describe a minimal model of emotion in robots in somewhat behavioristic view, which is based on Dietrich Doerner's theory on human emotions. From this perspective, we define five emotions of robots in terms of four modulators. Next, we conduct a robotic experiment in order to test that humans can identify a set of basic emotions in a mobile robot synthesized based on our definition This paper reports on the result of this evaluation test, and also discusses adaptive properties of each emotion by assuming illustrative examples in which a robot moves around an environment with various physical conditions.

Keywords: Emotional robots, Artificial life, Behavior modulation, Evolutionary psychology

1 Introduction

The study of emotions has become a hot research area during recent years [1]. Many researchers have focused on the functions of emotion, and typical explanations of them 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. Among them, Masanao Toda has developed a theoretical framework termed the urge theory in which human activities may be modelized, and has focused on the functional aspect of emotion systems [2].

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). We believe that the possession of emotion is an adaptive "trait" also to robots conducting their assigned tasks in environment with or without humans, which is parallel with a selectionist view that emotion in humans is the product of adaptive evolution.

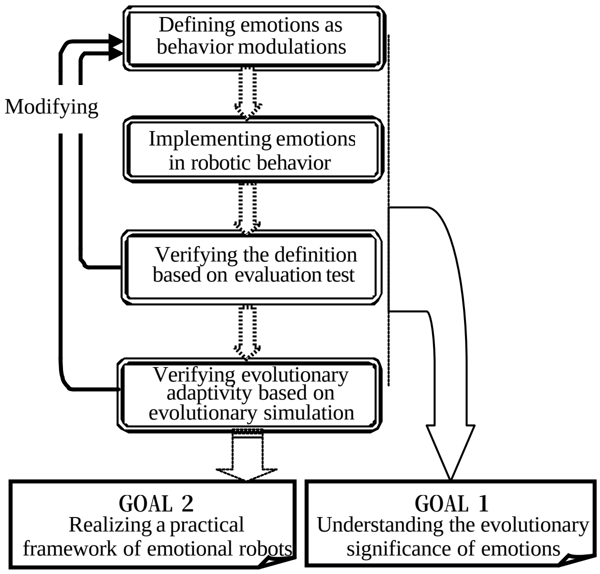


Fig. 1 Study scheme.

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.

As a first step, we describe a minimal model of emotion in robots, which is based on Dietrich Doerner's theory on human emotions, which is, in short, that emotions are seen as behavior modulations [3][5][6]. We define five emotions of robots in terms of four modulators based on his claim. Next we conduct a robotic experiment in order to test whether humans can identify a set of basic emotions in robots implemented based on the definition, which might remind of the impressive work of Valentino Braitenberg, in which, as thought experiments, he designed many simple vehicles and described them as possessing fear, love and aggression [4]. Our model of emotions in robots is functionalistic, and supposed to lead to evolutionary grounding. For this purpose, we discuss adaptive properties of each emotion by assuming illustrative examples in which robots move around an environment with various physical conditions.

2 Emotions as Behavior Modulations

We describe a minimal model of emotion in robots in somewhat behavioristic view in Section 3, which is based on the Dietrich Doerner's theory on human emotions. Doerner's claim is, in short, that emotions are seen as behavior modulations [3][5][6]. The theory identifies four different modulators that describe goal-directed behavior at any given time, a) activation, b) externality, c) precision, and d) focus.

a) **Activation**

The amount of nonspecific activation that is involved while pursuing a goal. This modulator has the extremes of hypoactivation (a lack of energy) and hyperactivation (a surplus of energy).

b) **Externality**

The proportion of time spent in external activity. This modulator has the extremes of introversion (devoted mainly to information processing) and extroversion (devoted mainly to action).

c) **Precision**

How much care or precision a goal is pursued with. This modulator has the extremes of imprecision and precision.

d) **Focus**

The amount of attention that is allocated to the current task rather than to the surveillance of the background. This modulator has the extremes of broadened senses and of narrowed senses.

Following analogy might help our understanding of emotions as behavior modulations [6]. 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 described by emotions as behavior modulations. We can notice a striking difference between the behavior of an angry person and that of a sad person even if they take the same action. The volume control and so on in televisions correspond to activation, externality, precision, and focus in the emotion systems. The variations of the behavior on these four aspects define the modulations of human behavior. Each modulation pattern is associated with a particular emotion as shown in Tab. 1.

Tab. 1 Modulation patterns of six emotions [6].

	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

3 Introducing Emotions to Robots

We conducted a robotic experiment in order to test whether humans could identify a set of basic emotions in a robot synthesized based on the above-described Doerner's theory on emotions by using a mobile robot "AmigoBot" (Fig. 2). The robot moved on a particular path from the start point to the goal point in a field where there existed some obstacles and walls as shown in Fig. 3. We defined following four modulators in behavior of the robot to synthesize emotional behaviors (Fig. 4).

Fig. 2 AmigoBot.

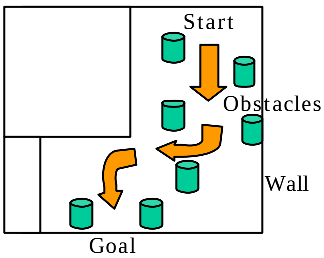


Fig. 3 Environment and Robot Task.

a) **Activation**

How long each behavior cycle is. The robot sets its behavior (motor speed) every behavior cycle.

b) **Externality**

How fast it moves through the path.

c) **Precision**

How long it deviates from the route at curves.

d) **Focus**

How much degree it deviates from the route. If it concentrates its task, it moves to the goal directly along the route. If not, it deviates from the route.

Fig. 5 shows the typical trajectories of a robot with emotions defined by 4 modulators and the modulation patterns shown in Tab. 1.

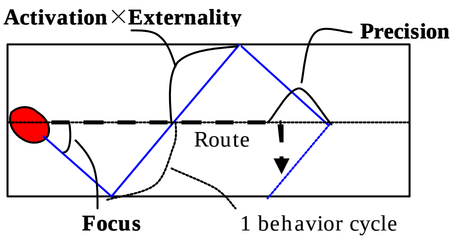


Fig. 4 Modulations of the robot behavior.

(Dashed line: Route, Solid line: Trajectory of a robot).

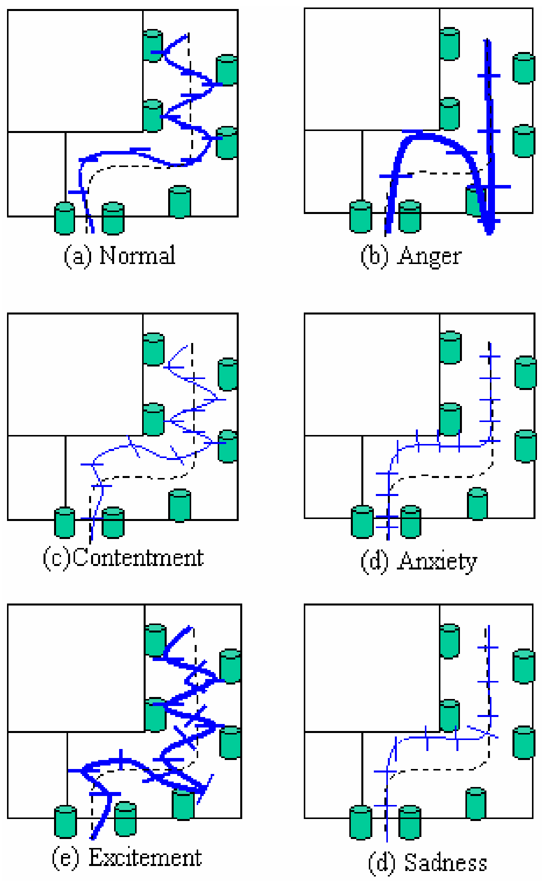


Fig. 5 A sketch of the robot trajectories with 6 emotions. (width of trajectories: robot velocity expressed by **externality**, length of each fragment: **activation*externality**).

4 Evaluation Test

We conducted an evaluation test in which the robotic behavior was estimated by more than 1000 subjects (visitors to a scientific museum) in order to test whether humans could identify a set of basic emotions in robots as described in the previous section. We captured five emotional behaviors and one behavior without emotion on movie files, and then human experimental subjects were required to assign five emotions to these five movie files after seeing and comparing them on the computer display (Fig. 6).

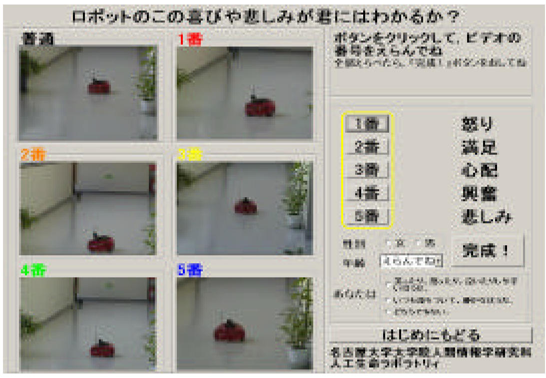


Fig. 6 A screen shot of the evaluation software.

Tab. 2 Human ratings of emotions.
(bold-type: the most frequently associated emotions).

Ratings / Shown Emotions	Anger	Content-ment	Anxiety	Excite-ment	Sadness	None	Total
Anger	**335**	119	102	220	182	155	1113
Contentment	151	**382**	237	121	110	112	1113
Anxiety	132	153	**268**	164	245	151	1113
Excitement	204	147	215	**310**	88	149	1113
Sadness	135	168	170	136	**331**	173	1113
Total	957	969	992	951	956	740	5565

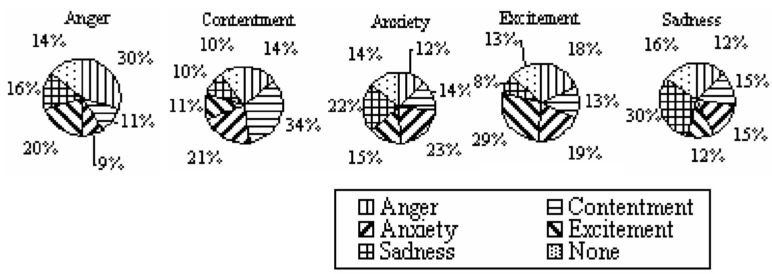


Fig. 7 Pie chart of human ratings of emotions.

The result of the experiment (Tab. 2 and Fig. 7) showed that subjects had a tendency to identify all of the basic emotions in the robot. The chi-square analysis showed significant relationship between the modulation pattern and the rating of the subjects (?2: 189.88, df: 16, P: 1.8044E-159), although the evaluation test was not conducted under the strict conditions. It was shown that three emotions: anger, contentment and sad were clearly distinguished from the other emotions, while anxiety was least identified. Also, anxiety and sadness which have similar modulation patterns tended to be confused, which seems rather reasonable.

5 Discussion

Here we discuss adaptive properties of some emotions in robots from a selectionist perspective by using illustrative examples. Suppose that a robot moves from the start point to the goal point in an environment with various physical conditions as shown in Fig. 8.

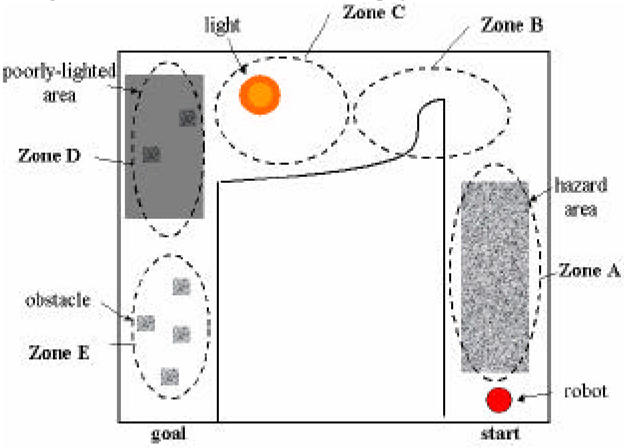
In this figure, Zone A is a hazard area, in which the robot suffers serious damage every second. So, it is adaptive for the robot to get angry when entering the zone, because most activation and most externality make the robot get out the zone in a rush even though least precision might cause dissipation of its some energy. Also, anger might be adaptive when moving the narrow path (Zone B). It would be difficult for a robot with careful moving to get out these zones. In contrast, tough actions of angry robot could go through such a path while bumping against walls at times.

Next, suppose that a robot moves in contentment. Its focus is least and activation and externality are low. Its relaxed move might have a tendency to let the robot find a light source and fill in its energy (Zone C). In case that a robot enters a poorly-lighted area (Zone D), it would be adaptive for a robot to become anxious, because accurate move with concentrated attention could let the robot find and clear the obstacles. Also, to be anxious might become adaptive in Zone E, as the robot could respond to irregular emergence of obstacles.

6 Conclusion

We have synthesized an emotion system "as it could be" in robots based on the view of emotions as behavior modulations. We conducted an evaluation test which looks something like the famous Turing test, and showed that humans could identify the five basic emotions from the emotional behaviors of a robot defined by modulation patterns. Adaptive properties of emotional behavior were also discussed based on illustrative examples. Our next step is to conduct evolutionary simulations to verify this sort of evolutionary adaptivity with the scenario of the origin and the evolution of human emotions in mind as shown in Fig. 1.

Fig. 8 An environment with various physical conditions.



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