Robot behavior decision based on Motivation and Hierarchicalized Emotions

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Abstract: In this paper, we propose the new emotion model and the robot behavior decision model based on proposed emotion model. As like in human, emotions are hierarchicalized in four levels (momentary emotions, mood, attitude, and personality) and are determined from the robot behavior and human responses. They are combined with motivation (which is determined from the external stimuli) to determine the robot behavior.

Keywords: Hierarchicalized Emotion, Emotion model, Robot behavior decision

1. INTRODUCTION

Emotion is one of the important factor in intelligence. Minsky indicated the importance of emotion-dealing capability in artificial intelligence and Damasio insisted the existence and the role of emotional intelligence. Goleman[3], Strongman[4], Kleinginna[5] defined the emotion and Picard[5], Ortony[6], Rosman[7], Bates[9], Reily[10] made the models of emotion.

Emotion model is studied for robot behavior decision by many researchers. Velasquez proposes emotion model named Cathexis and use it for emotion expression of SIMON the cyber-character in virtual environment. In Cathexis model, emotion is defined from the internal motivations (hungry, thirsty, curiosity, etc.) and environment (which is controlled by human). For example, when internal motivation curiosity is high and "toy" is given from environment, SIMON feels happiness and expresses this emotion as facial expression. Breazeal uses KISMET the robot. KISMET receives the camera image and expresses the intention of robot by actions such as changing of the facial expression, the neck status, and the ear position. The emotions are determined from the camera image and are used for determining the robot actions. Fujita uses emotions in different ways. He uses emotion model for AIBO (an entertainment dog-form robot of SONY.) This model includes six instinct variables which is changed according to the external stimuli thorough specific sensors (such as the switch in the robot back.) And the values of these variables inspire the emotions and emotions influence the behavior decision.

These models have limitations. The emotion models of Velasquez and Breazeal consider only the actions which are directly related with the emotions, such as facial expression. Non-emotional actions such as going forwards are not considered. The emotion models of Fujita defines the emotion is determined from actions which is distinguished from other actions which is influenced by emotion. Emotion can influence some actions, but these actions can not influencing the emotions. For the general human-robot interaction, these models need to be modified.

In this paper, we propose a new model in which emotion should influence the non-emotional actions and be influenced from the responses to actions which is determined by emotion. With this model, we build the behavior decision model for human-robot intelligent thorough robot actions and human responses.

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2. HIERARCHICALIZED EMOTIONS

The proposed model has the hierarchy consisting of 4 levels (Fig. 1), which is the extension of Wilson's Psychological models. Levels represent momentary emotions, mood, attitude, and personality and have the corresponding characteristics. Momentary emotion is defined for instantaneous robot behavior and human response, and mood is determined from the accumulated momentary emotions. Attitude is determined from the sequence of momentary emotions in pre-defined intervals and it is controlled by personality.

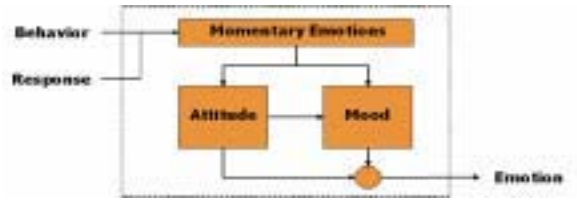


Fig. 1 Emotion model

2.1 Momentary emotions

Momentary emotions are modeled as 6 variables corresponding to Sorrow, Anger, Aversion, Surprise, Pleasure, Fear. This model is based on the psychological studies of Ekman[14], Ushida[15], Miwa[16], Masuyama[17] in which 6 emotions are selected and verified as useful emotion model. These momentary emotions are determined by the robot behaviors and human responses. In our model, the possible behaviors are 'Raise Hand'(Ra), 'Approach'(A), 'Avoid'(Av), and 'Wagging Tail'(W) and the possible humand behaviors are 'Recognize'(R), 'Attack'(At), 'Have'(H: when human give reward). The behaviors can be emotional ones or non-emotional ones.

The definition of momentary emotions using the given behaviors and response, are based on Masuyama's model. Masuyama defines each emotion as the logic expression which is TRUE when expression is satisfied or FALSE otherwise. For example, Sorrow is defined as in (1)

$$\forall s \forall t_{-1} \forall t_0 [sorrow(s,t_0) \equiv \exists x [want(s,have(s,x),t_{-1}) \wedge t_{-1} \le t_0 \wedge recog(s,\sim have(s,x),t_0)]] \quad (1)$$

With (1), emotion is determined clearly (either TRUE or FALSE, that is, emotion is inspired or not!), for very limited cases only. We want the momentary emotion to be defined for more various cases than (1). For this purpose, we define the

momentary emotions as in (2)

$$
\begin{aligned}
f_{Anger_k} &= \tfrac{1}{4}A_k + \tfrac{1}{4}W_k + \tfrac{1}{4}R_k + \tfrac{1}{4}(1-H_k) \\
f_{Surprise_k} &= \tfrac{1}{4}A_k + \tfrac{1}{4}Av_k + \tfrac{1}{4}R_k + \tfrac{1}{4}(1-H_k) \\
f_{Aversion_k} &= \tfrac{1}{4}Ra_k + \tfrac{1}{4}W_k + \tfrac{1}{4}At_k + \tfrac{1}{4}(1-H_k) \\
f_{Surprise_k} &= \tfrac{1}{4}A_k + \tfrac{1}{4}Av_k + \tfrac{1}{4}R_k + \tfrac{1}{4}(1-H_k) \\
f_{Pleasure_k} &= \tfrac{1}{4}Ra_k + \tfrac{1}{4}A_k + \tfrac{1}{4}R_k + \tfrac{1}{4}H_k \\
f_{Fear_k} &= \tfrac{1}{4}A_k + \tfrac{1}{4}Av_k + \tfrac{1}{4}(1-R_k) + \tfrac{1}{4}At_k
\end{aligned}
\qquad (2)
$$

In (2), each variable is 1 when corresponding behavior is selected or response is given, otherwise 0.

2.2 Mood

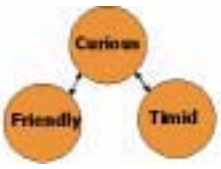
Moods are determined from the accumulated momentary emotions. Therefore, they are also modeled as 6 variables which are corresponding to 6 variables of momentary emotions. Each variable is determined by averaging the correspoding momentary emotion as in (3)

$$
\begin{aligned}
Sorrow_{k+1} &= \frac{f_{Sorrow,k} + k \cdot Sorrow_k}{1+k} \\
Anger_{k+1} &= \frac{f_{Anger,k} + k \cdot Anger_k}{1+k} \\
Aversion_{k+1} &= \frac{f_{Aversion,k} + k \cdot Aversion_k}{1+k} \\
Surprise_{k+1} &= \frac{f_{Surprise,k} + k \cdot Surprise_k}{1+k} \\
Pleasure_{k+1} &= \frac{f_{Pleasure,k} + k \cdot Pleasure_k}{1+k} \\
Fear_{k+1} &= \frac{f_{Fear,k} + k \cdot Fear_k}{1+k}
\end{aligned}
\qquad (3)
$$

$MOOD_k = [Sorrow_k; Anger_k; Aversion_k; Surprise_k; Pleasure_k; Fear_k]$ represent the long-term occurrences of momentary emotions.

2.3. Attitude and Personality

Attitude is a variable which has one of three possible values: Timid, Curious, Friendly. At every moment, attitude is changed when the past sequence of momentary emotions in pre-defined intervals satisfied specific conditions. Possible transition between attitude values and their conditions are given in Fig. 2.



(a) Possible attitude transition

Curious → Timid	$If\,(Timid\_Condition > W \cdot EMO_{average} \wedge Timid\_Flag = 1)$
Timid → Curious	$If\,(Curious\_Flag = 1)$
Curious → Friendly	$If\,(Friendly\_Condition > W \cdot EMO_{average} \wedge Friendly\_Flag = 1)$
Friendly → Curious	$If\,(Curious\_Flag = 1)$

$$
\begin{aligned}
Timid\_Condition &= \tfrac{1}{4}(f_{Sorrow} + f_{Aversion} + f_{Fear} + f_{Angry}) \\
Friendly\_Condition &= f_{Pleaure} \\
EMO_{average} &= \tfrac{1}{6}(f_{Sorrow} + f_{Angry} + f_{Aversion} + f_{Surprise} + f_{Pleasure} + f_{Fear})
\end{aligned}
$$

(b) Condition for attitude transition

Fig. 2 Transitions between attitude values.

Timid_Flag is set as 1 if one of f_{Sorrow}, $f_{Aversion}$, f_{Fear}, f_{Angry} becomes maximum among momentary emotions in H times, otherwise *Timid_Flag* is set as 0. *Friendly_Flag* is set as 1 if $f_{Pleasure}$ becomes maximum among momentary emotions in H times, otherwise *Friendly_Flag* is set as 0. *Curious_Flag* is set as 1 if the momentary emotions for current Flag are different from that for past Flag in H times, otherwise *Curious_flag* is set as 0.

There are parameters W and H in the attribute transition conditions. They are determined when the emotion model is implemented and will not be changed. These variables control the sensitivity of attitude over the changes of momentary emotions. If W and H are large, attitude does not easily change, while if W and H are small attitude changes very easily. For avoiding the chattering effect in this kind of systems, we should set W and H large, but if it is too large, the change of attitude becomes too slow to reflect the change of momentary emotions. Therefore it determines the system properties so that it is named as personality.

3. BEHAVIOR DECISION USING PROPOSED EMOTION MODELS

Psychological factor for behavior decision is called as motivation. It is the internal signal inspired from internal/external stimuli, and its effects on behaviors comprise the behavior decision model. But in this paper, we use this term "motivation" as the meaning of "the motivation except emotion." In this section, we define 1) very simple motivation model and its effect on behaviors, then define 2) the effect of emotion on behaviors. By 3) combining defined effects, we can construct the behavior decision model. Its overall relation is as in Fig. 3.

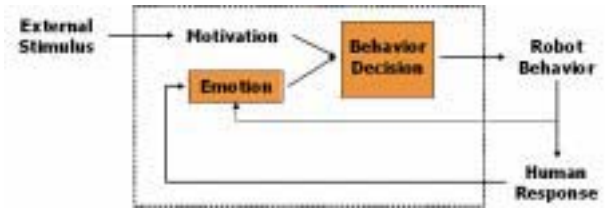


Fig. 3 The behavior decision model

3.1 Motivation

Motivation is very simple defined. Motivations are modeled as 4 variables (f_Play,k, f_Affection,k, f_SelfDefense,k, f_Satisfaction,k) corresponding to Play, Affection, Self_Defence, Satisfaction. Each has corresponding stimulus. If corresponding stimulus is given, the value of variable is set as 1. Otherwise, the value is set as 0. Corresponding stimulus for Play, Affection, Self_Defence, Satisfaction are “to see human”, “to see friend”, “to see enemy”, and “to see food”, respectively.

Each motivation is directly mapped to one behavior. Motivation "Play" inspires the behavior "Raise Hand",

"Affection" inspires "Approach", "Self Defense" inspires "Avoid", and "Satisfaction" inspires "Wagging Tails". "Inspire a Behavior" is implemented as increasing the value of a variable correspoding to a behavior. This relation is expressed as in (4)

$$\begin{bmatrix} f_{RaiseHand} \\ f_{Approach} \\ f_{Avoid} \\ f_{WaggingTails} \end{bmatrix} = BEHAVIOR = MOT = \begin{bmatrix} f_{Play} \\ f_{Affection} \\ f_{SelfDefense} \\ f_{Satisfaction} \end{bmatrix} \quad (4)$$

3.2 Emotion

The effect of emotion on behavior is determined by mood and attitude. This effect is defined as in (5)

$$BEHAVIOR = MOT = M(ATTITUDE) \cdot MOOD \quad (5)$$

Mood is multiplied by M to determine the behaviors. M is the matrix which is determined by attitude. We can design M to make it easy the selection of behaviors which are appropriate to current attitude. For example, in friendly attitude the friendly behaviors (such as. …) are more selected than other actions. By setting the corresponding row to large values, we can achieve this purpose.

3.3 Behavior decision model

Combining (4) and (5), we calculate the values for each behavior BEHAVIOR as in (6).

$$BEHAVIOR_k = \frac{1+\alpha k}{1+k} MOT_k + \frac{(1-\alpha)k}{1+k} EMO_k \quad (6)$$

In this equation, k is the iteration index. When k = 0, motivation dominate the behavior decision and as k increases, the effect of emotion is included in the behavior decision. Finally, when k is very large, motivation and emotion is reflected in behavior decision in ratio of a:1-a. This relation can be adjusted.

From BEHAVIOR, we can find the values for behaviors. Among behaviors, the behavior corresponding to maximum value is selected and carried out by robot. Then the behavior and human response to behavior is determined and given to robot. It updates the emotion and new behavior is selected. Through the repetition of this process, human and robot can interact with each other.

4. SIMULATION RESULTS

4.1 Behavior decision with only motivation

We set a in (6) as 1 so that the effect of emotion is ignored. We observe the behavior decision by the motivation only. Simulation is conducted until iteration count k = 50 and W and H are set to 0.85 and 5, respectively.

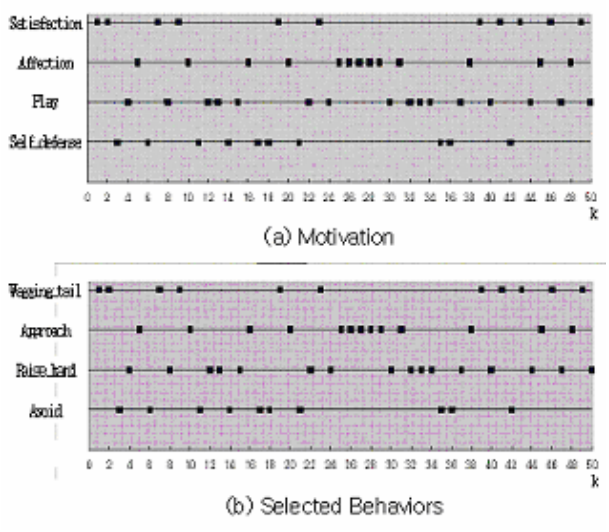


Fig. 4. (a) Motivation (b) Selected Behaviors

Motivations are given as in Fig. 4(a) by corresponding external stimuli and the selected behaviors are given in Fig. 4(b). As designed, 1-1 mapping between motivations and behaviors is observed.

4.2 Behavior decision with motivation and emotions

We set a in (6) as 0.4 so that the effect of emotion is not ignored. We observe the behavior decision by the motivation and the emotion. The result can be compared wih Fig. 4. Simulation is conducted until iteration count k = 50 and W and H are set to 0.85 and 5, respectively.

Emotions are given as in Fig. 5 by corresponding set of Behaviors and Responses given in the table in Fig. 5. Motivations are given as in Fig. 6(a) by corresponding external stimuli. The selected behavior and the attitude under these motivations and the emotions are given in Fig. 6(b) and Fig.6(c), respectively.

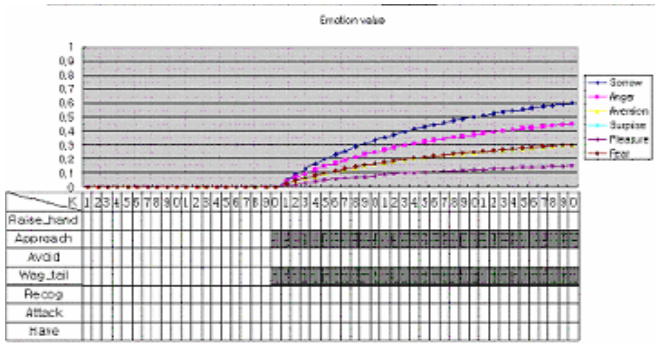


Fig. 5. emotions by given behavior and response set..

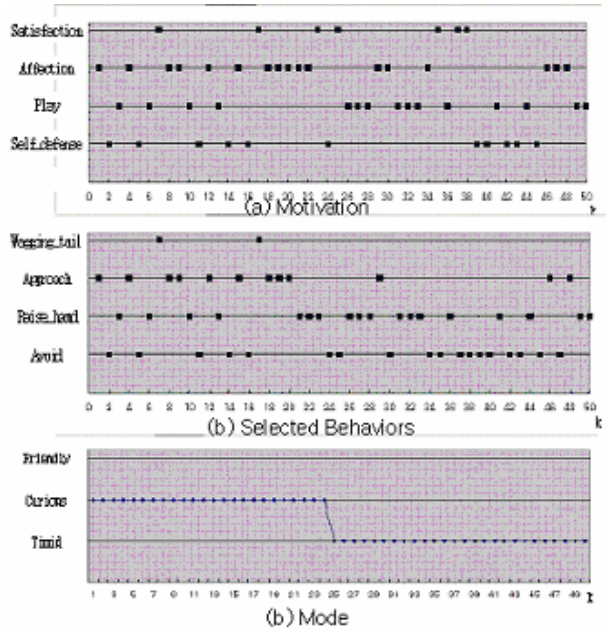


Fig. 6. (a) Motivation (b) Selected Behavior s (c) Attitude

Before k = 20, that is, when the emotion is not given, 1-1 mapping between motivations and behaviors is observed as in 4.2. But after k = 20, 1-1 mapping between motivations and behaviors is not observed. According to the attitude in 6(b), the behaviors in upper or lower place are more selected than others. It shows the effect of motivation.

4.3 Behavior decision under different presonalities

To observe the effects of personalities, we use three different pairs of W and H: (0.85, 5), (0.75, 2), (1, 8). In each case both the motivation and the emotion influence the behavior decision. We set a in (6) is set as 0.4 and experiment is conducted until k = 50.

Emotions are given as in Fig. 7 by corresponding set of Behaviors and Responses given in the table in Fig. 7. The determined attitudes for 3 different personalities (0.85, 5), (0.75, 2), (1, 8) are given in Fig. 8(a), Fig. 8(b), Fig. 8(c), respectively.

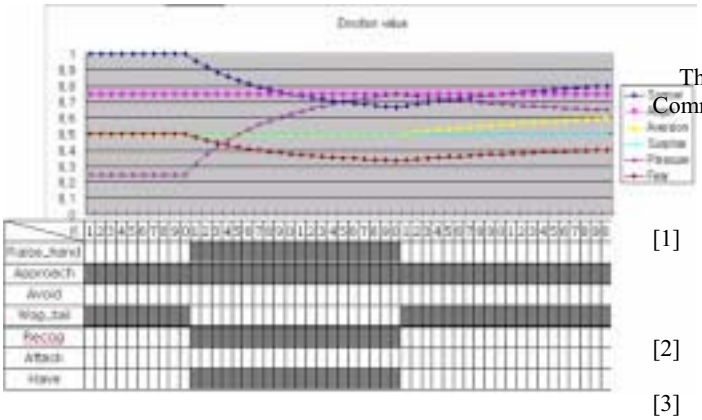


Fig. 7. emotions by given behavior and response set..

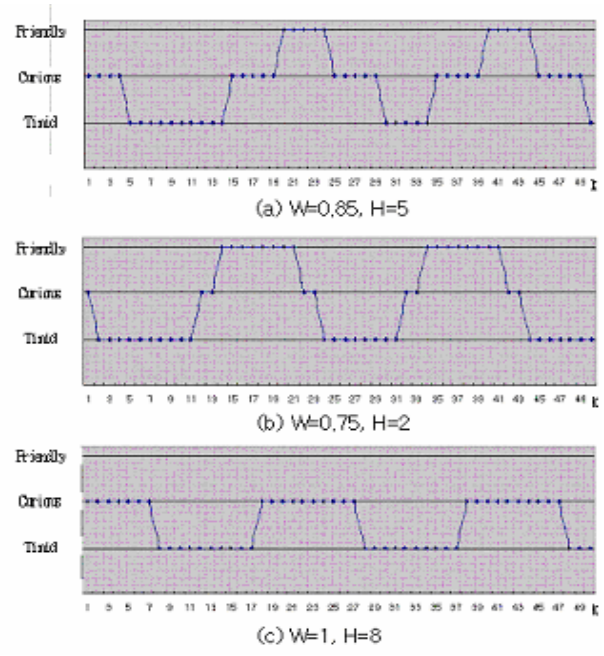


Fig. 8. The Change of Attitude when
(a) W=0.85, H=5 (b) W=0.75, H=2 (c) W=1, H=8

Compared with the attitudes in (a), the attitudes in (b) change fast and those in (c) change slowly. In (c), some changes are omitted because of slow change of attitudes. It shows the effect of the personality clearly.

5. CONCLUSION

In this paper, we propose the new emotion model and the robot behavior decision model based on proposed emotion model. As like in human, emotions are hierarchicalized in four levels (momentary emotions, mood, attitude, and personality) and are determined from the robot behavior and human responses. They are combined with motivation (which is determined from the external stimuli) to determine the robot behavior.

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