Modeling of the Emotional Model with Friendship for Familiarity of Robot

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Abstract—This paper deals with the emotional model of the software-robot. The software-robot requires several capabilities such as sensing, perceiving, acting, communicating, surviving and so on. There are already many studies about the emotional model like KISMET, AIBO. Though many emotional models are implemented their human respond architectures are invariance as time passed. Conventional emotional models make robot like and obey human during robot operation. This is natural for robots which are used in industrial, service and military areas but about pet robots this property let robot be looked like real robot not real pets. Actually robot's emotional model is studied to implement robot intelligent more easily but emotion expression have to be exaggerated in pet robot to give interesting to human. Pet robots must show dynamical emotion variations. The emotional model with the modified friendship is studied in this paper to overcome conventional emotional model's limits to apply on pet robot. Friendship is distinguished as positive, negative and static scheme and emotional model with the modified friendship is implemented and simulated on software-robot.

Index Terms—Human-robot interaction, friendship, artificial emotion.

I. INTRODUCTION

Recently, pet robots and amusement robots have been developed as the next generation of electronic toys. They aim to mimic the real dogs or pets and to be friends of human. The pet robots require several capabilities such as sensing, perceiving, acting, communicating and surviving. With these pet robot can be looked like the real dogs or pets but they have limits to mimic real lives. To overcome limits many emotional models are introduced in [1], [3], [7]. Conventional emotional models have common internal structure such as recognition, perception, planning and learning though details are different. Their studies have focused on constructing and making relation among each internal blocks and remodeling each block by their own theories. Also conventional studies commonly have been obeyed the rule that robot must follow and like human. So finally their react to human is set to like and obey human. When they are powered start to like human until be broken. This characteristic of robot makes robot not real pets but real robot.

In this paper, a new emotional model is proposed to make pet robots or toy robots to perform behaviors similar to that of real pets. A real pets does not get around with a human suddenly. Rather, it takes some times for interactions before treating a human as a friend. This kind of emotional mechanism is implemented by modeling friendship capability. In general, friendship means only positive relation but definitely with interaction between two people or between a human and a pet they can have bad relationship also. Moreover, humans or pets can have good emotions between them just because they live nearby, even though they may not have any special interaction. Considering this, the modified friendship is proposed. In other words friendship is resolved in to positive and negative forms that represent good and bad relationship. In addition to that, static friendship is defined to represent good relationships that are generated with no special interaction.

Section 2 describes detail of friendship scheme and mathematical modeling. Section 3 describes the overall structure of emotional model with the modified friendship scheme. Section 4 explains the simulation results of software-robot which have the emotional model with the modified friendship scheme. Section 5 discusses and concludes the contribution of this work.

![Fig. 1. Robot reaction](image)

II. FRIENDSHIP

Usually robot decides his next action based on current states, such as emotion, motivation, intention and so on. These
kinds of internal states induce the final robot action, which is
decided directly. For example, when robot heard a complaint
from human, the robot would refuse to follow his commands,
and on the other hand, when robot heard praise from the
human, the robot would follow his commands. Direction
of (1) and (2) in fig.1 are conventional robot reaction. In
conventional emotional model robot reaction always is in the
action pool to like or dislike human such as fig.1- (1) and (2).
Whenever robot hears bad sound he refuse human order but
real pet or human doesn’t do like that. If time doesn’t go much
after pet meets the human above rule is affected, but after
time goes much if friendship is bigger than nominal value pet
dure the complaint from human and obey human’s order.
This mechanism needs friendship. Friendship gives tolerance
and variation to emotion, motivation, intention and result in
the action such as fig.1 - (3) and (4).
The meaning of friendship is extended to describe good,
bad and static relation which means good relation generated
by sharing space or contacting eyes with no intended special
interaction. To describe each friendship, positive, negative and
static friendship is modeled.

A. Judge human intention of bitting based on friendship

Robot has to judge whether human bitting is purely bad
action or just freak of good emotion by the rate of positive
friendship to negative friendship. If positive friendship is
bigger than negative friendship by some nominal value robot
can think this bitting or complaint is just freak or bitting based
on likeness. If positive friendship is smaller than negative
friendship by some nominal value robot can think human
really dislike robot because human has been bitten robot
during almost operation time. \( f_{avoid} \) is defined as a basis
of judging human intention in (3). At first (1) and (2) are
explained to describe (3).

\[
E_{positive}(t) = f_{HI} \times f_{E_{p}} \times w_{e} \times \int_{t_0}^{t} E(\tau)d\tau \quad (1)
\]

\[
E_{negative}(t) = f_{HI} \times f_{E_{n}} \times w_{e} \times \int_{t_0}^{t} E(\tau)d\tau \quad (2)
\]

where \( E_{positive} \) is sum of emotion values which have
positive values like happy. \( E_{negative} \) is sum of emotion values
which have negative values like anger and sad. \( f_{HI} \) is flag
which is set while human robot interaction. \( HI \) is human
interaction. For \( f_{E_{p}} \) and \( f_{E_{n}} \) each is flag which is set while
robot is anger or sad and robot is happy, \( w_{e} \) is positive value
of weight. \( E \) is emotion value including happy, sad and anger.
(3) are described using (1) and (2).

\[
f_{avoid} = \begin{cases} 
1, & \text{if } \frac{E_{positive}}{E_{negative}} > \tau_a \\
0, & \text{otherwise}
\end{cases} \quad (3)
\]

where \( f_{avoid} \) is binary value to indicate robot’s judge on
human action. \( E_{positive} \) and \( E_{negative} \) is defined in (1) and
(2). \( \tau_a \) is a rate of positive value.

Robot decide current human intention based on rate of two
terms, (1) and (2). In common sense human judge other’s
bad action based on other’s action history. Assume that there
are three guys, A, B and C. B’s praise who consistently has
itten A can be recognized as curse, while C’s complaint who
consistently has had good relation with A can be recognized
joke. This judging mechanism is implemented using the
history of emotion between human and robot. If enough rate
of good relation exist comparing to bad relation it is supposed
that there is enough friendship between human and robot.
So if (1) is bigger than (2) with some rate robot recognize current
human bitting as just kidding or joke. If it doesn’t robot think
human bitting robot because human really dislike robot.

B. Modeling of friendship

Friendship is modeled to express robot’s familiarity to
human. Positive friendship is good relation between human
and robot, which is friendship in common sense. Negative
friendship has opposite property with positive friendship. It
makes robot think human’s praise as bad sound and freak.
Static friendship is actually parts of positive friendship. Ac-
ccording to speaker human feel completely different emotion
when listen some nervous joke. If speaker is intimate friend
human feel good emotion based on assumption that it is just
funny joke which makes human feel good emotion but if
speaker isn’t intimate friend or is stranger nervous joke can
be really serious and nervous announce. Static friendship is
proposed to express the former. It is increased at each time
when positive friendship is bigger than negative friendship
by some late and emotion activation is happened. Mathematical
model of friendship is described in (4) \(~ \sim \) (6).

\[
F_{positive}(t) = E_{positive} - E_{negative} - w_{f} \quad (4)
\]

\[
F_{negative}(t) = E_{negative} - E_{positive} - w_{f} \quad (5)
\]

\[
F_{static}(t) = f_{avoid} \times f_{HI} \times f_{E} \times \int_{t_0}^{t} w_{x}d\tau \quad (6)
\]

where each of parameters described such as follows. \( F_{positive} \) is positive friendship, \( F_{negative} \) is negative friend-
ship. \( F_{static} \) is static friendship. \( E_{positive} \) and \( E_{negative} \) are
defined in (1) and (2). \( w_{f} \) and \( w_{x} \) is positive value of weight
for each friendship, \( t_{0} \) is initial time. \( t \) is evaluation time.
\( f_{avoid} \) is defined in (3). \( HI \) is human interaction. \( f_{HI} \) is flag
which is set while human robot interaction happened.

(4) and (5) describes each about positive friendship and
negative friendship. Each of (4) and (5) is only available when
\( F_{positive} \) or \( F_{negative} \) is positive. In (6) static friendship is
piled up as time goes if interactions between human and robot
are happened and if robot’s emotion is activated.

III. OVERALL STRUCTURE OF EMOTIONAL MODEL

In Section 2 the newly modified friendship is described and
modeled. In this section the overall structure of emotional
model is presented using the newly modified friendship
scheme, fig.2. The most of block have been implemented in previous works, [1], [3], [7]. The new ones are friendship block and action selection block. Details of the software-robot’s emotional model are followed.

- **Sensor**: This block transfer the external stimuli to a numerical index.
- **Perception**: Knowledge reasoning about environment are happened using sensor block output.
- **Motivation**: Give the motivation to each activated perception. Motivation is different based on the layer of activated sensors.

\[
\text{Layer } k : \quad M_i = M_{i\text{init},k} \times e^{-w_k(t-t_{\text{init}})} \quad (7)
\]

where \(i\) is sensor number, \(t_{\text{init}}\) is sensor activation time, \(k\) is layer, \(w_k\) is positive number such as \(w_1 \geq w_2 \geq w_3 \geq w_4 \geq w_5\). \(M\) means motivation values such as \(M_{l\text{init},1} \geq M_{l\text{init},2} \geq M_{l\text{init},3} \geq M_{l\text{init},4} \geq M_{l\text{init},5}\.

Fig.3 shows roughly property of each layer's motivation. The characteristic of each layer of reaction is followed.

- **Layer1**: Reaction about the most reactive stimuli which require instant response to survive.
- **Layer2**: Most of reactive stimuli which have no effect on robot activity though that doesn’t reacted.
- **Layer3**: Mainly related to explorer, obstacle avoidance and wall following reaction.
- **Layer4**: Human interaction related reaction.
- **Layer5**: doesn’t need instant reaction like long distance obstacle, sound of virtual environments.

Because layer 1, 2 require a moment reaction their initial value is high but steeply decreased. Layer 4 is about human robot interaction so to be looked as real life robot must show reaction though it is not instant reaction.

- **Intention**: These state values are given to mainly human interaction reaction and object in virtual environment. Intention has exploit property. For example when human order ‘come’ robot must obey within a temporary time and the strength of obligation must be increased after stimuli activation to keep this intention.
\[ I_i = I_{init} \times e^{wt(t-t_{init})} \]  

where \( i \) is sensor number, \( t_{init} \) is sensor activation time, \( w \) is positive number of weight, \( I \) means Intention values.

- Emotion : Emotion is implemented similarly with conventional works, [1], [3], [7]. Five states of emotions are defined such as happy, sad, anger, boring and nor. Boring has different characteristic with other emotion. Other emotion except boring are varied when related stimuli are excited but boring is varied when robot focus on same action for some sampling times.

- Mood : Mood is already studied in previous works, [3]. In previous works mood is defined as sum of all activated emotion. Naturally mood must go to zero state as time goes while no external stimuli. Considering this property mood is defined like (9).

\[ \text{Mood}_{after}(t) = \int_{t_{init}}^{t} E(t)dt + \pm w_m \times t + \text{Mood}_{before}(t_{init}) \]  

where \( t_{init} \) is emotion manifestation time, \( t_{end} \) is emotion manifestation end time. \( w_m \) is positive weight. Sign of \( w_m \) is dependent on current mood value. If \( (\text{mood} > w_m) \) sign is negative, else if \( (\text{mood} < -w_m) \) sign is positive. \( |\text{mood}| \) is decreased to zero as time passed.

- Friendship(positive, negative, static) : Friendship is defined in (4), (5) and (6).

- Mission : The activation of mission is depend on friendship degrees. Suppose that robot playing with human without any interesting object. Then if very interesting object is appeared robot can move his focus on new object. In this case mission flag set by friendship degrees force robot to focus on human consistently.

- Action selection : Decide the robot action based on friendship, emotion, intention, motivation and mission. Basically robot action is selected by sum of intention and motivation. Additionally friendship increase intention related to human and object interaction and emotion increase or decrease motivation about current action depending on emotion states.

- Memory : This block save history of activated sensor, perceptive and action. This information guide robot to modify his internal states.

**IV. SIMULATION STUDIES**

Proposed emotional model with the modified friendship is tested on software-robot, [10]. Two types of simulation are executed by scenario about positive friendship affection and negative friendship affection. Software-robot is coded with Visual C++, and tested on Pentium4 2.4GHz PC with 512MB ram. One software-robot, one human, one ball are used in virtual environment to test proposed emotional model. Initially robot like human and ball equally but because priority of ball is higher than human, motivation difference between ball and human makes robot focus on ball at the beginning of simulation. Ball’s layer is 3 and human’s layer is 4 on robot’s view point in (7).

**A. Positive friendship test**

To test positive friendship affect scenario is supposed. Scenario is like that at the beginning of simulation robot more focus on ball than human because of motivation. After some times passed robot begin to like human more than ball by interaction with human. In other words positive friendship which has been increased by praise makes robot like human even though human’s complaint. Praise and complaint is representative of good and bad stimuli to make robot’s happy and anger emotion activated.

Simulation results show that at begin time robot focus on ball and continuing of praise increase positive friendship. Finally robot like human more than ball and focus on human. Focusing on human robot chase the human and don’t care ball on the way to reach human and though human’s complaint keep chasing the human. Fig.4 to Fig.10 shows detail of internal states of robot during simulation time.

Mood goes to zero while there are no emotion activations as intended. Fig.10.

**B. Negative friendship test**

Scenario is similar with positive friendship test. At the beginning of simulation robot focus on ball more than human. After human appear on virtual environment eye contact between human and robot is happened. Eye contact increase positive and static friendship and makes robot like human. By acting complaint consistently after enough time passed, robot’s negative friendship is increased. Finally continued complaint makes robot dislike human and like ball more than human. Robot chase the ball though human is on the way to go ball. Fig.11 to Fig.17 show internal states of robot during negative friendship increasing. Noticeably Fig.12 to Fig.14 shows negative friendship is bigger than positive friendship by enough difference and robot’s \( F_{negative} \) is available while \( F_{positive} \) is unavailable.

**V. CONCLUSION**

The emotional model with the modified friendship is implemented. Proposed emotional model makes robot more familiar to human and intelligent. Specially friendship is extended as negative, positive and static scheme to make robot looks like more real life.

Mood is also modified. It is natural that all kind of emotions must go to zero states without any continuing excitation. Previous works [3] doesn’t care decreasing property of mood. Proposed mood in this paper has property of decreasing by time and make robot act more naturally.

In proposed model deciding a last action is concerning many internal states, emotion, motivation, intention, friendship and mission. To merge many internal states designer must tune the strength of each state. This is heuristic. Designing a tuning method to mixing many internal states is needed.
Fig. 4. Focus variation (Positive Friendship)

Fig. 5. Positive friendship variation (Positive Friendship)

Fig. 6. Negative friendship variation (Positive Friendship)

Fig. 7. Static friendship variation (Positive Friendship)

Fig. 8. Intention variation (Positive Friendship)

Fig. 9. Motivation variation (Positive Friendship)

Fig. 10. Mood variation (Positive Friendship)

Fig. 11. Focus variation (Negative Friendship)
Fig. 12. Positive friendship variation (Negative Friendship)

Fig. 13. Negative friendship variation (Negative Friendship)

Fig. 14. Static friendship variation (Negative Friendship)

Fig. 15. Intention variation (Negative Friendship)

Fig. 16. Motivation variation (Negative Friendship)

Fig. 17. Mood variation (Negative Friendship)

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