

A Virtual Entertainment Robot Based on Harmonic of Emotion and Intelligence*

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Abstract — A virtual robot called Hubot (Humanoid robot) is proposed to enhance entertainment and to highly personalize human-machine interaction. The model of Hubot integrates emotional system with intention system. The extended situation calculus including affective computing is used to describe the model. Fuzzy representation is used to capture the inherent uncertainty of emotion and cognition. Finally, the correctness and validity of the model is proven by an experiment of comparison.

Key words — Virtual robot, Affective computing, Situation calculus, Human-machine interaction, Electronic entertainment.

I. Introduction

The entertainment industry evolves so fast; the quality of commercial computer games and animated cartoons is directly related to their entertainment value.

Now AI comes to become a key factor in determining success of computer games and animated cartoons. Many researchers would consider that virtual robots should be whole autonomous in future: they interact with the virtual world by their virtual body; adapt their environment by various learning algorithms^[1].

Actually simulating virtual robots enables developers to add biologically plausible errors to the interaction with the environment. Including such biologically plausible details allows the virtual robots to behave more realistically. To most AI developers, such research in biologically plausible emotion systems sounds extremely promising. In many ways, artificial emotions represent an ideal complement to classical AI. Therein reside our interests from a developer's perspective: emotions are a key factor in realism and believability. With emotions, all virtual robot behaviors would seem more realistic and generally increase the immersiveness of the virtual environment. Each of these features increases entertainment value^[1].

A model is proposed for customizing automatically Non-player characters (NPCs) according to the player's temperament and players can enjoy characters with personalities that reflect human behavior^[2]. In some experiments, the NPC

can change its facial expression according to its emotion like the human to attract game players^[3]. Karim Sehaba explains an emotion model for synthetic characters with personality^[4]. But few work focused on creating artificial life based on harmonic of emotion and intelligence for entertainment. We have attempted to create our virtual entertainment robots and called them Hubots (Humanoid robots).

II. The Model

Recently, neurological evidence has indicated, contrary to what most people believe, that emotions are essential and that they serve a substantial function in human intelligence. Arguments are made based on neurological evidence that not having "enough" emotion can bring disaster into our behavior and actions. It is hypothesized that stimuli are processed under two different perspectives, perceptual layer and cognitive layer; and the assessment of a stimulus is sent to cognitive layer from perceptual layer^[5].

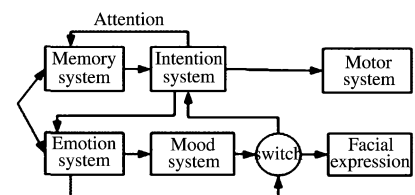


Fig. 1. The model of virtual robots based on harmonic of emotion and intelligence

Our current model is depicted in Fig.1. In response to an external stimulus, the emotion component and the memory component both extract a reduced set of essential features. In the emotion component, there are two direct maps. One is between stimulus and desirability and another is between emotions and moods. On the other hand, in the memory component, the stimulus is temporarily stored. If the intention component decides to pay attention to the stimulus, it sends a signal to the memory component. As a result, the memory component creates a cognitive image which is rich enough to allow a fairly good reconstruction of the original stimulus and the original stimulus is reserved much long time.

Emotion or mood can produce facial expressions with a very low threshold, *i.e.* generating facial expressions is reactive (we ignore other reactive behaviors). Once an emotion or

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mood is selected by the intention component with its intensity above a certain threshold which is not the same value as generating expressions, then the intention component sends a signal to the memory component and later selects a proper motor. Sometimes the intention component can generate an emotion to either replace or inhibit the current emotion, for example, a policeman searching a robber can generate an intension or an expectation to inhibit his fear.

III. Intention System

The situation calculus is a well known formalism for describing changing worlds using sorted first-order logic. It can also be used to describe how an autonomous character's knowledge of its world changes. The basic idea is that a character views its world as a sequence of "snapshots" known as situations. An understanding of how the world can change from one situation to another can then be given to the character by describing what the effect of performing each given action would be. The character can use this knowledge to keep track of its world and to work out which actions to do next in order to attain its goals^[6].

An autonomous character would be able to reason about the effect of its actions. It would, therefore, be able to choose a course of action that it believed would result in a desired effect. Unfortunately, the world the agent was to be situated in was highly complex. To some degree, the result of its actions would be unpredictable. In this article, we propose an alternative approach to solve non-deterministic actions based on epistemic fluent K and a new Linguistic variable epistemic (LVE).

1. Linguistic variable epistemic fluent

Fuzzy control techniques could be integrated into the logical formalism of the situation calculus^[7]. We propose an alternative epistemic fluent using linguistic variables within the situation calculus, based on interval-valued fluents John Funge proposed^[6].

The approach will treat interval-valued fluents as linguistic variables, the members of which are fuzzy sets defined on the interval. For each sensory fluent f , a new corresponding Linguistic variable epistemic (LVE) fluent L_f was introduced to solve uncountable number of possible worlds and reason about inequalities. First we give the following definitions.

Definition 1 Given a fuzzy set A defined on X and any number $\alpha \in [0, 1]$, the α -cut, $[A]_\alpha$, is the crisp set ($\bar{M}$ denoting the closure of set M).

$$[A]_\alpha = \begin{cases} \{x|x \in X, A(x) \geq \alpha\}, & 0 < \alpha \leq 1 \\ \overline{\{x|x \in X, A(x) > 0\}}, & \alpha = 0 \end{cases} \quad (1)$$

Definition 2 Let $a = [a-, a+]$ and $b = [b-, b+]$. $a \prec_2 b$ if $a- \leq b-$ and $a+ \leq b+$.

Definition 3 Let A and B be fuzzy sets defined on X . $A \prec_2 B$ if $[A]_\alpha \prec_2 [B]_\alpha$ for any $\alpha \in [0, 1]$.

Definition 4 A LVE fluent is characterized by a quad $(\Psi, T(\Psi), U, M)$ in which Ψ is the name of the fluent; $T(\Psi)$ (or simply T) denotes the term-set of Ψ , that is, the set of names of linguistic values of Ψ , with each value being a fuzzy

variable denoted generically by X and ranging over an interval U which is associated with the base variable u ; and M is a semantic rule for associating with each X its meaning, $M(X)$, which is a fuzzy subset of U . X is constrained by

$$[X_1]_0 \cup [X_2]_0 \cup \dots = \cup [X]_0 = U \quad (2)$$

$$X_1 \prec_2 X_2 \dots \quad (3)$$

where $X_1, X_2 \dots$ are all fuzzy subsets of Ψ .

2. Sensing

The effects of non-deterministic actions can only find out by sensing. Sensing is the only knowledge producing action, and its effect is to make some fluents become known but don't change the world^[6]. Given a sensing action P_ω , we can use the axiom:

$$Poss(a, s) \wedge a = P_\omega \Rightarrow [\forall s_i (K(s_i, s) \wedge \omega(s_i) = \omega(s))] \quad (4)$$

In all the K -related worlds^[6], for any a , we just wrote down the following formula

$$\forall s_i (K(s_i, s)) \Rightarrow K(do(a, s_i), do(a, s)) \quad (5)$$

Thus, for each LVE ω , the corresponding successor state axiom for K is then^[6]:

$$\begin{aligned} Poss(a, s) \Rightarrow & [K(s'', do(a, s)) \\ & \Leftrightarrow \exists s' (K(s', s) \wedge (s'' = do(a, s'))) \\ & \wedge ((a \neq P_\omega) \vee (a = P_\omega \wedge \omega(s') = \omega(s)))] \end{aligned} \quad (6)$$

The above successor state axiom captures the required notion of sensing and solves the frame problem for knowledge producing actions.

IV. Modeling Emotions

Our computational model of emotions, which is an extension of the Cathexis model^[8], was built to integrate perception, attention, motivation, emotion, behavior, and motor into specific circuits.

1. Basic emotions

The expression of basic emotions has been used in many different ways. In this thesis, the term basic is used to emphasize how evolution has played a significant role in forming the unique and common characteristics that emotions exhibit, as well as their current function. However, as a first step towards addressing the complexity, the model deals with the following basic emotions: Happiness, Anger, Fear and Sadness.

Emotion is defined to a LVE fluent *emotion* in the situation calculus:

$$T(emotion) = \{happiness, anger, fear, sadness\} \quad (7)$$

Evidence suggests that emotions dynamically interact in important ways which should be considered in a comprehensive model of emotions including basic and mixed emotions. In our model, the mixture of emotions will be filtered to get one emotion according to their priority and intensity. Fear has a high priority; Anger, Sadness and Happiness have a low one. According to Definition 4 above, we have that:

$$happiness \prec_2 sadness \prec_2 anger \prec_2 fear \quad (8)$$

The intensity of emotions is represented as linguistic variables, each of which consists of three memberships or more, describing the intensity as low, medium, or high etc.. We introduce a LVE fluent $intensity(x, s)$ that gives the intensity of emotion x in the current situation.

From Definition 2 above, we can easily infer that:

$$[0, 0] \prec_2 [1, 1] \prec_2 \cdots \prec_2 [n, n] \quad (9)$$

where $0, 1, \dots, n$ are integer. Since $[n, n]$ has width 0 we can re-write this as:

$$0 \prec_2 1 \prec_2 \cdots \prec_2 n \quad (10)$$

So we begin by expanding out definitions:

$$T(intensity) = \{0, 1, 2, \dots, n\} \quad (11)$$

The emotion with the highest intensity and the highest priority will be chosen. This type of interaction is consistent with real life emotional systems, in which high arousals will tend to inhibit other emotions. The effect axiom is of the form:

$$emotion = e_1 \Rightarrow \neg \exists (emotion = e_2 \wedge e_1 \neq e_2 \wedge intensity(e_1, s) \prec_2 intensity(e_2, s)) \quad (12)$$

2. Moods

A layered approach is introduced for modeling emotions and moods in this thesis. Unlike other models^[8], temperaments are not modeled, but they can act on the model through changing the activation threshold. The changes in moods are generally triggered by the emotions of virtual robots. The moods correspond directly to the emotions in our model, and they are Dread, Hatred, Sorrow and Joy, respectively corresponding to those emotions: Fear, Anger, Sadness and Happiness.

The interaction of moods is similar to the emotions, however, there is no consideration about reaction to the emotions.

Mood is defined to a LVE fluent $mood$ in the situation calculus:

$$T(mood) = \{dread, hatred, sorrow, joy\} \quad (13)$$

The transitions between these moods are determined by changes in the emotions, for example:

$$Poss(a = fear, s) \Rightarrow emotion(s) = fear \wedge mood(s) = dread \quad (14)$$

3. Emotion recognition

The current psychological and neurophysiological evidence indicates that emotions are so closely associated with cognition that it is nearly impossible to isolate the two aspects within a complex biological system^[8].

All emotions can be triggered from memory through the intention component, and we also assume that the intention component maybe produce some emotions such as anger etc. according to data synthetic character collected in a statistical fashion and experiences synthetic character possessed when assessment of a stimulus is sent to the intention component. It is possible that fear and happiness with low intensity can be replaced by anger and sadness through intention component process. The intention component can also bring on enough

expectation to inhibit other emotions. When an expectation is satisfied, then happiness is released.

Each emotion can be recognized by a precondition axiom, for example:

$$\begin{aligned} Poss(a = fear, s) &\Leftarrow enemy(s) \wedge (distance(s) = close \\ &\vee (distance(s) = far \wedge number(s) = mass) \\ &\vee (distance(s) = far \wedge number(s) = few \\ &\wedge fire(s) = power)) \end{aligned} \quad (15)$$

Here, *enemy*, *distance*, *number*, and *fire* are LVE fluents.

For example, in Fig.2, a Hubot was trying to find the monster with blended moods (joy 4, hatred 2, and dread 1 are LVE fluents); suddenly they met by chance and the Hubot felt fear at sight of the huge and dreadful monster; and the Hubot cried with sad voice when it was hit by the monster's magic during fight. Here it is assumed that facial expression is of sort action.

4. Emotion decay

Emotions can be very brief, typically lasting just a couple of seconds and at most minutes, i.e. once an emotion is generated, it does not remain active forever. After some period of time, unless there is some sort of sustaining activity, it disappears. In our model, we assume that emotions only last a few time cycles.

Moods last much longer than emotions, thus their intensities will decay more slowly. In our model, we provide with a built-in decay function, which controls the duration of the moods once they have become active. The moods also seem to lower the threshold for arousing the intention component.

Suppose we have an action *tick* that occurs once per some cycles. Then according to Eq.(12), we can have an effect axiom that states the emotion or mood is changed after a period of time.

$$\begin{aligned} Poss(tick, s) \wedge (\exists x, emotion(x, s)) &\Rightarrow \\ \{ [intensity(x, s) = n \wedge n > 0 \\ &\Rightarrow intensity(x, do(tick, s)) = n - 1] \\ \vee [intensity(x, s) = 0 \Rightarrow \neg emotion(x, s)] \} \end{aligned} \quad (16)$$

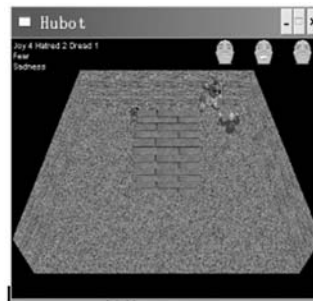


Fig. 2. A moment in game demo (the last three facial expressions are shown at the top right corner of the window)

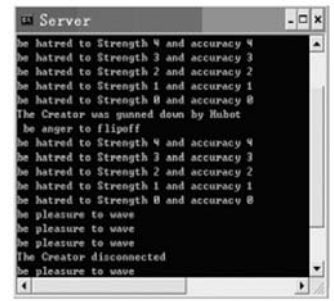


Fig. 3. The change course of emotion of Hubot

For example, in Fig.3, the output of the server console recorded the change course of emotion of a Hubot, from the

player character entering the demo 1 map of game Quake 2 and firing at the Hubot to its being defeated. During the course, the Hubot expressed anger twice, each time lasting 1 tick. Anger generated hatred which lasted 5 ticks.

5. Action selection

Evidence suggests that the emotion experience has powerful influences on action selection. After being activated, the emotion component can generate what are termed desirability vector. A desirability vector represents a basic kind of assessment of a stimulus. As soon as receiving a desirability vector, the intention component pays attention to the stimulus and selects a proper behavior. We assume that only one desirability vector can be selected to execute at a given time, thus there exist competitions among the desirability vectors produced by internal and external stimulus, the being executed or the waiting, according to their priority and intensity. What's more, the mood component can also have an influence on decision making or action. In Fig.3 above, it was shown that emotions and moods had impacts on strength and shooting accuracy in decay.

V. Experiment

The architecture of Hubot is represented by formula below

$$IMP \Leftrightarrow T_a \circ T_{st} \circ T_s \quad (17)$$

where functions T_s , T_{st} and T_a denote sensing, the extended situation calculus and effecting respectively, and the implementation of the model is the product of them. T_s and T_a are the interfaces which are responsible for connecting *sensing* and *action* in the situation calculus, and users communicate with the situation calculus by the two interfaces. Additionally, the user can also make Hubots learn by interface T_i .

With the help of the open source FEAR (<http://fear.sf.net/>), Hubots can be applied to a commercial first-person shooter game engine Quake 2. User can create vary kinds of Hubots by implementing the three interface and editing the extended situation calculus.

In the experiment, we compared three kinds of bots (intelligent bot, Hubot and traditional reactive bot) who respectively fought with a Player character (PC). The intelligent bot (ibot) was equipped with the same knowledge as the Hubot in addition to not including emotion. The traditional reactive bot (called bot) were supplied by Quake engine.

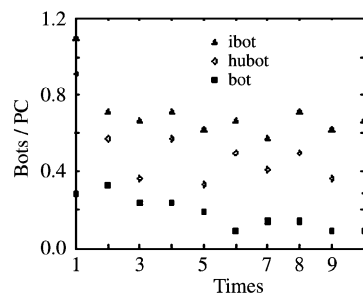


Fig. 4. Comparison among the intelligent bot, the hubot and the reactive bot fighting against the player character

The result shows the fact that including such plausible emotion allows the Hubot to behave more realistically and entertainment (see Fig.4).

In Fig.4, the times of game play is the x-coordinate and the winning ratio of some bots to PC is the y-coordinate. The graphic shows that the PC can easily beat the

reactive bot with more fighting times (Solid square), but hardly to defeat the intelligent bot (triangle solid). Compare with the reactive bot and intelligent bot, the Hubot locates between them (diamond).

VI. Conclusions

In this paper, we presented a new model for modeling virtual entertainment robots. Based on synthetic agents, we integrate emotional systems with attention, intention and expression system to enhance the entertainment. The system is formalized in an extended situation calculus.

The model discussed here is a simple prototype of an emotional system including few emotions and moods. Few details about human-machine interaction are mentioned, such as facial expression recognition^[9].

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