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Emotion-based planning evaluation method

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Abstract: It has been recently suggested by a number of researchers that emotional systems in agents might have great practical value. In this paper, we propose a system that makes decision about a plan, basing its judgment on emotion (i.e. pleasure/displeasure) extracted from knowledge, in an attempt to build a human-like computer agent, better able to communicate with users. We present an emotion-based plan evaluation method, and then provide the result simulated on naturally occurring short-story scenarios and show that plan evaluation based on artificial emotion generated by our method successfully matches the one based on human emotion.

1 Intruduction

Since the advent of Information Age, human-computer communication has been an important aspect in our life. However, computers are not human-friendly enough to establish a very close relationship. One of the reasons for that sense of distance is derived from our stereotyped image of computers as "emotionless", as we often describe emotionless people as machine-like. As the collaboration between humans and autonomous computer agents is becoming more and more common, the need for a computer, better able to communicate with human users, will inevitably arise. We believe that emotion is one of the primary requirements for such computer systems. Our research goal is to build a human-like computer agent embodied with a system that uses emotions as heuristics for decision-making process in planning.

A lot of research efforts have been made to explore emotion in order to build emotional agents that appear to be more like humans, better able to interact with human users. AESOPWORLD system[1], for example, is

capable of expressing its emotions with background music, and Sakai's system[2] is capable of generating situation-based facial expressions. These emotional agents are designed to achieve a better human-computer communications by adding emotion-expressing capabilities to the current systems. Human emotions, however, not only play such additional roles, but also affect more important decision-making.

The aim of the paper is to propose a system that makes decision about its action plan, whether or not to adopt a certain plan, basing its judgment on its emotions (pleasure/displeasure) extracted from its own knowledge structure, rather than simply expressing emotions generated. The system first predicts events for when it does/does not adopt a certain plan. It then evaluates its emotional degree of like/dislike for each of the events, and makes a final decision for whether or not to adopt the plan, depending on its preference.

In this paper, the emotions of an agent are represented by the status 'like /dislike' or 'pleasure/displeasure,' the agent has towards an event or a plan.

Section 2 of the paper proposes an emotion-based plan evaluation method. Section 3 provides results simulated on short love-story scenarios in order to examine the validity of the presented method.

2 Emotion-based Plan Evaluation Method

2.1 Decision flow of the agent

The architecture of the agent consists of three components: (1) Knowledge Control, (2) Favorable Value Data and (3) Plan Evaluation.

(1) The Knowledge Control component stores events that represent the agent's knowledge and past experiences. These events are stored in a contradiction-free manner in accordance with Truth Maintenance System (TMS). This component receives a plan to be evaluated and predicts events for both when it does and does not adopt the plan. (2) The Favorable Value Data component controls the agent's preference data for a person or an object. The events in the Knowledge Control componet are used to calculate Preference-for-Plan Value and to predict likely future events. (3) The Plan Evaluation component computes Emotion Value that the agent will generate for predicted events both when the plan is and is not activated, and makes final decision whether or not to adopt the plan.

Figure 1 shows the decision flow of the system. The agent first receives a plan to be evaluated. The Knowledge Control component of the architecture predicts likely future events for both when the plan is/is not carried out, and then calculates the degree of pleasure/displeasure the agent has for each event, using Emotion Generating Calculations (EGCs) that will be presented later. Favorable Value, a variable used for EGCs, is obtained from the Favorable Value component. With the degree of pleasure/displeasure for each predicted event, it finally makes decision whether or not to adopt the plan.

In the following sections, each of the components will be discussed in detail.

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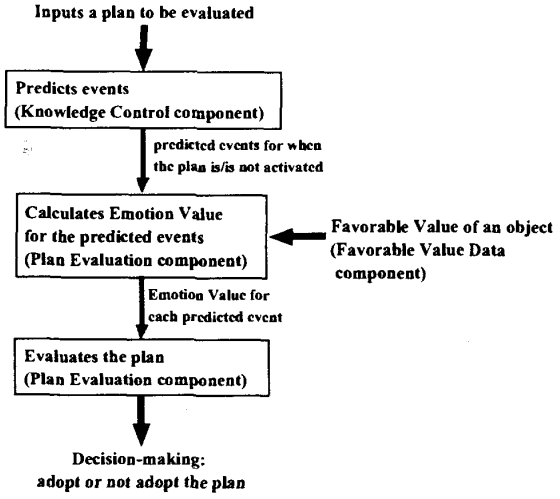

Figure 1: decision flow of the system

2.2 Plan Evaluation Component

This is the main component of our agent architecture in which an Emotion Value is computed utilizing Emotion Generating Calculations, as a pre-step to the final Plan Evaluation.

2.2.1 Emotion Generating Calculations

In this paper, we use EGCs to evaluate Emotion Value, the degree of pleasure/displeasure that the agent feels towards each predicted event[3][4]. The equations for EGCs are prepared for each event type that is represented in the form of a case-frame structure. There are a total of 8 types of equations. See the papers [3] and [4] for details. The agent's emotion is calculated by substituting each case element of the structure for its Favorable Value that will be discussed in detail in 2.4.

Let us present an example calculation.

Event : "Kyota dates with Kiriko."

$$\begin{bmatrix} Predicate(P) & = "dateswith" & : +0.5 \\ Subject(S) & = "Kyota" & : +1.0 \\ ObjectMutual(OM) & = "Kiriko" & : 0 \end{bmatrix}$$

Event type: "date with" $\rightarrow$ V(S, OM)

$$\Downarrow$$

$$\begin{aligned} \text{Emotion Value} &= f_S(I) * f_{OM}(Kiriko) * f_P(dateswith) \\ &= (+1) * (+0.1) * (+0.5) \\ &= +0.05 \rightarrow positivenumber(alittlepleasant) \end{aligned}$$

This example calcutes Emotion Value for the event above from the viewpoint of Ryota's. Emotion Value is a real number between -1 and 1. Favorable Value for oneself is defined as +1.0. The result shows that the agent feels a little pleasant about the event "Kyota dates with Kiriko."

2.2.2 Preference-for-Plan Value

Next, the agent's Preference-for-Plan Value is calculated using Emotion Value described in the previous section. Preference-for-Plan Value indicates whether or not the agent likes to adopt a plan. The equation is as follows:

$$Pv = (\sum Ain - \sum Aout) - (\sum Nin - \sum Nout)$$

Pv:	Preference-for-Plan Value
Ain:	Emotion Value for predicted events generated when the plan is activated
$Aout$:	Emotion Value for predicted events deleted when the plan is activated
Nin:	Emotion Value for predicted events generated when the plan is not activated
$Nout$:	Emotion Value for predicted events deleted when the plan is not activated

When the computed value is a positive number, it means the agent likes the plan and will adopt it. When the value is a negative number, the agent does not like the plan and will not adopt it. In a short, the agent makes a choice so that more favorable and less unfavorable events will be created in its knowledge structure.

2.3 Knowledge Control Component

In this component, world knowledge and experiences gained by the agent are structured based on the cause-effect relationships. Truth Maintenance System (TMS) is used in order to control the knowledge[5]. One piece of knowledge is described on an event-by-event basis, in the form of a case-frame structure.

In the decision-making process, this component anticipates events when a plan is supposed to be activated, by taking an input: an event "this plan is activated," in the current knowledge structure. Predicted events are a set of events that are generated or deleted according to TMS when a plan is/is not supposed to be activated. The component anticipates events also when time passes without any plan actions. This anticipation does not affect the actual knowledge structure.

2.3.1 Event Data Description

In the Knowledge Control component, each event is described with four features as follows.

Event no.:	positive number
Description:	case-frame structured
Reason:	TMS-based reasoning
True/False:	in/out

An event is numbered and is described in a case frame structure, and is implemented by the four types of reasoning: presupposition, assumption, conditional proof and support list justification, and defined as "in" when the statement is true and as "out" when false.

Let us look at an example event.

Event no.: 1
Description: (is a loose woman ((Subj Kiriko)))
Reason: (assumptions 5,6)
Truth/False: in

This indicates that an event #1 "Kiriko is a loose woman" is recognized as true, guessed by the two assumptions: a friend's rumor (event #5) and witnessing a burry (event #6).

Inference rules consist of two parts.

Condition: conditions for applying a rule

Action: activated when condition is realized

Condition: (kiss ((Subj P1)(Goal P2)))
Action: (love ((Subj P1)(Obj P2)))

This indicates that if "P1 kissed P2", it means "P1 loves P2."

2.4 Favorable Value Data component

This component calculates Favorable Value for an element contained in a case-frame structured event that will be used in the aforementioned EGCs in the Plan Evaluation component. Favorable Value is the degree of like/dislike that the agent has for a certain object contained in an event. The value has two types: a predefined value for a predicate of an event, and a knowledge-dependent value for a case element. Favorable Value for an element varies depending on knowledge the agent has about an object. The value naturally increases when an object does something useful or favorable to the agent. It decreases, on the other hand, when an object does something harmful or unfavorable. Favorable Value for a predicate of an event is currently assigned a pre-determined numerical value.

In our approach, Favorable Value for an object is calculated by extracting such situations as will influence its Favorable Value, from the agent's knowledge structure. Such situations are called Favorable Value Changing Situations, and are defined with the following three rules.

Condition: events

Situation: situations represented by events

Favorable Value change: increase/decrease

Here's an example.

Condition:(date ((Subj P1)(Goal P2))) and (date ((Subj P1)(Goal P3)))
Situation: P1 is dating with two persons at the same time.
Favorable Value change: FV for P1 decreases

This example indicates that the agent "dislikes a person who dates with two person." The situation in which a person P1 is dating with two persons causes Favorable Value for P1 to decrease.

Favorable Value is a figure between -1 and 1. In this method, Favorable Value for an object is defined as the number of subtracting the number of its Favorable Value decreasing situations from the one of its Favorable Value increasing situations, multiplied by α. α is a coefficient for $-1.0 \sim 1.0$.

This Value is obtained from the knowledge structure, and varies according to its change, for example, by acquiring new knowledge though learning and conversation.

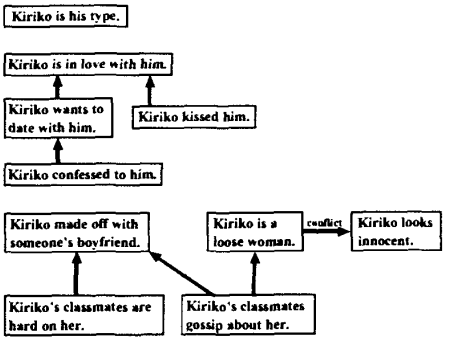

Figure 2: Kyota's knowledge structure before Kiriko's friend convinced him

3 Experiments

Our method was simulated on the following naturally occurring short love story scenario. 27 Favorable Value Changing Situations were previously hand-extracted from 48 short love stories to be used in the simulation.

One day, Kiriko, who was gossiped as being a loose woman by her classmates, confessed that she was in love with Kyota. Judging from what she looked like, Kyota could not believe that the rumor was true, but neither could he totally deny it. He suggested to her that they should stay as just friends(1). Kiriko, who was hurt to know that he believed in the rumor, declined his suggestion. The next day, Kyota, who was convinced by Kiriko's friend that the rumor was not true, decided to accept her(2).

Figure 2 shows Kyota's knowledge structure before Kiriko's friend convinced him.

3.1 Emotion Generating Calculations

EGCs used for calculating Emotion Value for an event require Favorable Value for an enormous number of objects in the world knowledge.

Out of our 8 Emotion Generating Calculations, the simplest type of equation is picked for the experiment. This equation is a linear function with a single coefficient of Favorable Value for a subject case element. This coefficient is calculated by performing the regression analysis based on the questionnaire results conducted to investigate human emotions toward an event.

3.2 Favorable Value Changing Situations

World knowledge-based Favorable Value Changing Situations are countless and extremely individual-dependent. As it is impossible to describe all such situations, we limit the situations to the ones found in the domain of romance. For the experiment, 27 Favorable Value Changing Situations that occur more than one time in the stories are used.

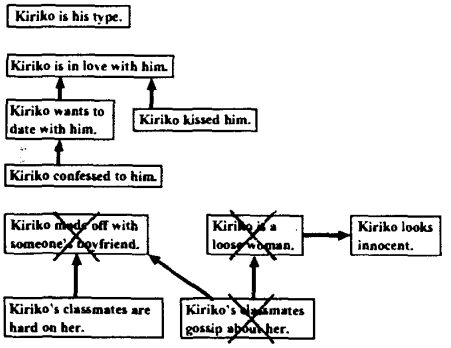

Figure 3: Kyota's knowledge structure after Kiriko's friend convinced him

3.3 Simulation

Kyota's emotional state was simulated in the scenario presented above. The result shows his emotional change (1) before and (2) after he was convinced by Kiriko's friend.

Kyota's Favorable Value for Kiriko is calculated based on the knowledge structure before he was convinced by Kiriko's friend, as shown in Figure 2. Figure 3 shows his new knowledge structure after he was convinced by Kiriko's friend.

The following Favorable Value Changing Situations are obtained from the knowledge structure in Figure 2.

- (+) Kiriko is Kyota's type.
- (+) Kiriko likes Kyota.
- (+) Kiriko confessed to Kyota.
- (−) Kiriko is a loose woman.
- (−) Kiriko made off with someone's boyfriend.

The result shows that Favorable Value for Kiriko is +0.1, computed by the following equation: (3-2)*0.1= 0.1. The events predicted for when Kyota dates with Kiriko and when Kyota does not date with Kiriko are as follows.

Kyota dates with Kiriko	does not date
Kiriko becomes his girlfriend. Kyota has a loose girlfriend. Classmates gossip him.	Kiriko gets sad.

With Emotion Value for every predicted event, Preference-for-Plan Value is computed to be -0.78, which consequently motivates the agent not to adopt the plan "Kyota dates with Kiriko."

After Kyota was convinced by Kiriko's friend, however, he found out that the rumor was not true. The knowledge structure, accordingly, changes, as shown in Figure 3. The new Favorable Value for Kiriko and predicted events are as follows.

- (+) Kiriko is Kyota's type.
- (+) Kiriko likes Kyota.
- (+) Kiriko confessed to Kyota.

Kyota dates with Kiriko	does not date
Kiriko becomes his girlfriend. Classmates gossip me.	Kiriko gets sad.

Favorable Value for Kiriko increases from +0.1 to +0.3, since a predicted event "Kyota has a loose girlfriend" is deleted by TMS. This change results in Preference-for-Plan Value of 0.2175, which suggests that the agent will adopt the plan. This result matches the actual decision-making described in the scenario. In other words, plan evaluation based on artificial emotion generated by our method agrees with the one based on human emotion.

4 Conclusion

We have presented our emotion-based plan evaluation method. The system consists of three components: (1) Knowledge Control, (2) Favorable Value Data and (3) Plan Evaluation. The three components are integrated to compute how much the agent likes or dislikes the plan in order to decide whether or not to adopt it. The system first predicted predicts events for when it does/does not adopt a certain plan . It then evaluates its emotional degree of like/dislike for each of the events, and makes a final decision for whether or not to adopt the plan, depending on its preference. The method was simulated on a short scenario using 27 Favorable Value Changing Situations and one type of EGC equation. This result matches the actual decision-making described in the scenario.

The Knowledge Control component is currently controlled by TMS. When the method is applied to world knowledge, it has to handle a tremendous number of events, which will most probably cause a huge processing cost. We need to consider excluding unreliable events and inference rules and preventing inference from going beyond a certain depth.

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