Design and Implementation of GEmA: A Generic Emotional Agent

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Abstract

In several successful researches, it is concluded that some other factors are effective in human behavior in addition to rationality. These factors are known as emotions and morality. These factors must be taken into account in intelligent agents to have human-like behavior. In this article, we concentrate on emotional aspects of decision-making. In this research, a new computational model is introduced to map the environmental events and agent actions to emotional states. The main characteristics of this model are adaptable to different domains and can be implemented as an individual module in software agents and it has been implemented as a library with JAVA and C# programming languages.

Keywords: Emotion, Emotional agent, Generic emotional model, Intelligent agent.

Without love, without anger, without sorrow, breath is just a clock ticking
(Wimmer, 2002)

1 Introduction

Many researchers in artificial intelligence as well as in operations research focused mainly on rational decision-making. However, emotions, such as joy, fear, hope, and anger have an important role in human behavior (Zinn, 2006). Hence, both the social and computational sciences have seen an explosion of interest in emotions in the last decade (Gratch, Marsella, & Petta, 2009).

1.1 Emotions and Decision-making

Historically, a conflict has been perceived between emotions and reason. It was advised that emotions should not be considered for reasonable decision-making. Gardner (1983) proposed the concept of "multiple intelligences" and divided intelligence into six types. In this theory, single IQ test could not determine a person's intelligence. Further studies showed emotions have a clear and important role in the decision-making process (Damasio, 1994; LeDoux, 1996). Later, Goleman (1995) introduced the phrase "Emotional Intelligence Quotient" (EQ). EQ describes the abilities of identify, assess, understand, and manage emotions (Mayer & Salovey, 1997).

1.2 Emotional Agent

"Inspired by the psychological models of emotions, researchers on Intelligent Agents have begun to recognize the utility of computational models of emotions for improving complex, interactive programs" (El-Nasr, Yen, & Ioerger, 2000). Minsky (1986) concluded that: "The question is not whether intelligent machines can have any emotions, but whether machines can be intelligent without any emotions". According to this conclusion, several models are represented that agent's decision-making and behavior appear more believable.
"Agents are autonomous software modules with perception and social ability to perform goal-directed knowledge processing, over time, on behalf of humans or other agents in software and physical environments. Additional abilities of agents are needed to make them intelligent and trustworthy. Abilities to make agents intelligent include anticipation, understanding, learning, and communication in natural language. Abilities to make agents more trustworthy as well as assuring the sustainability of agent societies include being rational, responsible, and accountable. These lead to rationality, skillfulness and morality (e.g., ethical agent, moral agent)"(Ghasem-Aghaee & Ören, 2003). Intelligent agents require the emotional factors in their decision-making processes to display behavior analogous to humans. For example, agents can model user's emotions and adapt interfaces to the user's needs. An agent with anger filter evaluates the degree of anger that the agent may feel when it encounters to a persecuting event (Ghasem-Aghaee, PoorMohamadBagher, Kaedi, & Ören, 2007). Adamatti et al. (Adamatti, Lucia, & Bazzan, 2001) presented a framework for simulation of agents with emotions. Chown et al. (Chown, Jones, & Henninger, 2002) described a cognitive architecture for an interactive decision-making agent with emotions. André et al. (André, Klesen, Gebhard, Allen, & Rist, 2000) focused on models of personality and emotions to control the behavior of animated interactive agents.

Emotion has broad impact across a variety of disciplines such as:

(1) Integration of emotions in the agent based tutoring system (Gratch, 2000; Poel, Akker, Heylen, & Nijholt, 2004; Vicente, 2003);

(2) consideration of emotions in project management and team configuration (Gareis, 2004; Miranda & Aldea, 2005; Miranda, Aldea, & Alcántara, 2003; Nair, Tambe, & Marsella, 2003; Whatley, 2004);

(3) response of military units to stress (Gratch & Marsella, 2003) and fear (Nair et al., 2003);

(4) the capability of forces in balancing a great deal of competing goals (Johns & Silverman, 2001);

(5) management of mental resources (Zadeh, Shouraki, & Halavati, 2006);

(6) estimation of emotions from text and annotation of emotions (Aman & Szpakowicz, 2007; Matsumoto, Ren, Kuroiwa, & Tsuchiya, 2007; Shaikh, Prendinger, & Ishizuka, 2007, 2009);

(7) relating prices, discounts, satisfaction and disappointment as well as supplier reputations and consumer choices (Mengov, Egbert, Pulov, & Georgiev, 2008);

(8) design and implementation of brain emotional based learning intelligent controller (BELBIC), which is based on mammalian middle brain, on a hardware platform (FPGA) (Jamali, Arami, Dehyadegari, Lucas, & Navabi, 2008).

1.3 Structure

In this paper, we present GEmA, a Generic Emotional Agent. The goal of our research is to create GEmA, as general computational model of the emotion mechanisms. The model is implemented as a C# and JAVA library. This library is adaptive to different domains and can be used modularly in different realistic applications. We can use the outputs of the model to determine the behavior of emotional agents.

Section 2 outlines some existing emotional models; Section 3 describes the structure of GEmA. In sections 4, GEmA library is illustrated. Section 5 describes its implementation and finally section 6 presents the conclusion and future work.

2 REVIEW OF SOME EXISTING EMOTIONAL MODELS

Throughout the history of AI research, many models were proposed to simulate the emotional process. In the following subsections, we focus on the prominent models which use OCC model (Ortony, Clore, & Collins, 1988) as a part of their appraising process and briefly discuss the following: Affective Reasoner (AR), EM Architecture, Fuzzy Logic Adaptive Model of Emotions (FLAME), Scalable, Hybrid Architecture for the Mimicry of Emotions (SHAME), and Emotion and Adaption (EMA).

Affective Reasoner (AR) models a multi-agent world and gives simple affective life to agents in the form of elementary emotions, emotion-induced actions and elementary personalities (Elliott, 1992). Agents are able to experience 24 emotion types and 1400 emotion-induced actions. These emotions have different conditions to get elicited. Each condition has a discrete value, which represents whether it is true or false. For example, Joy is triggered if a desirable event occurs. Portion of mood which affects the appraisal of agent is implemented in agents' working memory.

Agents have a two-part personality, including an *interpretive* part, which construes the world and leads to different emotional responses to situations that arise; and an *expressive* part, which controls how they express emotions. This model requires a number of domain-specific rules to appraise events. We use a domain independent method in GEmA to appraise events as well as actions.

EM Architecture is used in OZ project for emotions and social behavior (Bates, 1992; Reilly, 1996). The aim of the OZ project was to provide the users with the experience of living in dramatically interesting micro-worlds that include moderately competent emotional agents.

Each agent initially has preset attitudes towards certain objects in the environment. Further, each agent has some initial goals and a set of strategies that it can undertake to achieve a specific goal. The agent senses or perceives an event in the environment. The desirability of the event is associated with probability of goal attainment (Gratch & Marsella, 2004). This system relied on domain-specific rules to derive the probability of goal attainment (Gratch & Marsella, 2004) as well as expectations (El-Nasr et al., 2000). We use a dynamic method to derive expectation from past experiences of the agent.

Fuzzy Logic Adaptive Model of Emotions (FLAME) is a computational model of emotions based on event appraisal (El-Nasr et al., 2000). It incorporates some learning components to increase the adaptation in modeling emotions. It used fuzzy rules for mapping events to emotions and emotions to behaviors.

FLAME uses a learning method to learn the user's patterns of behavior to compute the expectedness of an action. We have modified this method to compute expectedness of an action as well as an event in GEmA that we discuss in the next section.

FLAME uses Markov-decision processes (MDPs) to calculate desirability of actions and events. Hence, "it can only represent a relatively small number of state transitions" (Gratch & Marsella, 2005). In other words, if the domain has large number of goals and events, then a large number of fuzzy rules are needed (Kazemifard, Ghasem-Aghaee, & Ören, 2006). It can be an obstacle to modulate the model. GEmA uses a mathematical method to calculate desirability of events as well as praiseworthiness of actions.

Scalable, Hybrid Architecture for the Mimicry of Emotions (SHAME) is a top-down approach for modeling the event appraisal by training neural networks (Kesteren, 2001). These networks are trained by a trainer, who learns the network examples of events and emotions that should be elicited by these events. Events have been categorized by considering OCC's event types. Each event appraiser is trained for specific domain so they are domain-dependent. Each neural network needs training. Providing training data from environment is not easy. The intensity of each emotion (between 0 to 100) is determined based on domain variables and it does not use generic rules for computation. For example when an agent with SHAME architecture takes an apple, its joy intensity is 100 minus amount of food and when the agent takes water, its joy intensity is 100 minus amount of water. GEmA provided general rules to compute emotions in the basis of the standard variables of OCC model.

Emotion and Adaption (EMA) developed general and domain-independent algorithms to support appraisal (Gratch & Marsella, 2004). It used decision-theoretic planning techniques to calculate the impact of events on goals and appraisals. For the intensity of emotions, two parameters are used: probability of goal attainment and goal importance. EMA is updated and developed with recent developments in the model (Marsella & Gratch, 2009). The new work also models a naturalistic emotional situation in EMA that involves both rapid and slower emotional responses. This model simulated only six emotions, joy, distress, hope, fear, anger, and guilt. EMA appraises only the category of goal-based emotions of OCC while the standards are important in appraiser. GEmA simulates sixteen emotions by appraising events and actions respect to both goals and standards of agents.

3 GEMA: A GENERIC EMOTIONAL AGENT

The overall architecture of GEmA is illustrated in Figure 1. The elements of the architecture are discussed in the sequel:

Appraiser includes two elements: *Event appraiser* and *Action appraiser*, which evaluate the events and actions of agent and other agents in the basis of agent's goals and standards. The OCC model (Ortony et al., 1988) is selected for events and actions assessment the reason is that it includes comprehensive local and global variables to compute intensity of emotions and methods for the assessment of the events and actions. In appraiser, a new assessment method discussed in next sections is used. The outputs of this module are degrees of desirability, realization, and praiseworthiness.

Update emotional states specifies the intensity of sixteen of the emotions of OCC model. It contains many rules to compute the intensity of emotions. To compute emotion intensity, one global variable and four local variables of OCC are used. The values of these variables come from different elements in the model. The local variables are desirability, realization, praiseworthiness, and likelihood; the global variable is expectedness.

Event and Action Repository works with events and actions by its two elements: *Pattern Table* and *Event and Action History. Pattern Table* learns the pattern of events and actions. The patterns are used to compute expectedness. This element uses a modified method in FLAME (El-Nasr et al., 2000). *Event and Action History* stores the occurrence of events and actions to compute the likelihood of the occurrence of an event or an action. The likelihood is computed for desirable events in hope emotion and for undesirable events in fear emotion.

Decay reduces the emotions at each cycle.

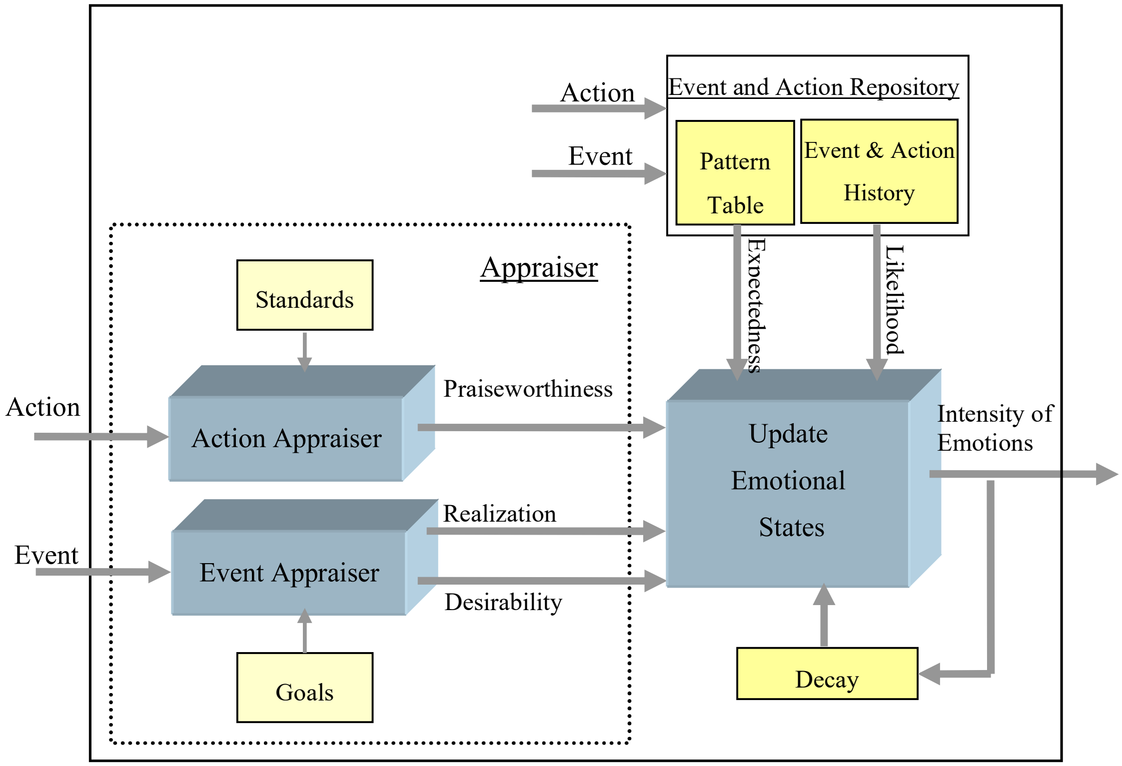

Figure 1: Architecture of GEmA (A Generic Emotional Agent)

3.1 Event and Action Appraisers

The structure of the event appraiser is similar to action appraiser. The terms Goals, Events, and Desirability in event appraiser are replaced with Standards, Actions, and Praiseworthiness in action appraiser. Hence, only event appraiser is presented here. However, we have to be careful about the concept “standard” which relates to belief of the agent and manner of behaving. It means the source of standards value differ from that of goals (Ortony et al., 1988). For example in the Virtual Tutor domain the student may have the “Do not ask Help” standard.

A complete evaluation of events, require the following points:

1. Each agent has a number of goals with different importance as indicated in weighting factors.
2. The degree of impact of input event on agent goal(s)
3. The degree of desirability to be determined by using points 1 and 2.

The following method is used to determine desirability. In this method, the goals and their importance are shown as vectors named *Goals* and *G* respectively: (Eq. 1)

$$Goals = \begin{pmatrix} goal_1 \\ goal_2 \\ \dots \\ goal_n \end{pmatrix} \qquad G = \begin{pmatrix} g_1 \\ g_2 \\ \dots \\ g_n \end{pmatrix} \forall i \in [1,n] : g_i \in [0,1] \tag{1}$$

Where g_i is the importance of each $goal_i$. To show the impact of events on goals, an *Impact* matrix is used. Each element of the impact matrix is the impact degree of *i*th event on *j*th goal; where *m* is the number of events and n is the number of goals:(Eq. 2)

$$Impact(e_i, g_j) = \begin{pmatrix} \alpha_{11} & \alpha_{12} & \dots & \alpha_{1n} \\ \alpha_{21} & \alpha_{22} & \dots & \alpha_{2n} \\ \dots & \dots & \dots & \dots \\ \alpha_{m1} & \alpha_{m2} & \dots & \alpha_{mn} \end{pmatrix} \tag{2}$$

$$\forall i \in [1,m]; j \in [1,n] : \alpha_{ij} \in [-1,1]$$

The desirability of each event can be computed by using the following formula: (Eq. 3)

$$Desirability(e_i) = \frac{\sum_{j=1}^{n} \alpha_{ij} g_j}{\max(\sum_{j=1}^{n} g_j, 1)} \tag{۳}$$

$$\forall j \in [1,n] and \forall i \in [1,m], Desirability(e_i) \in [-1,1]$$

To compute the impact of an event on goals, we consider a goal attainment method. In this method, we need to organize the goals as a hierarchy. We used the macrostructure model purposed by Ortony (Ortony et al., 1988). It models the goals in a tree structure. The high-level nodes represent fairly abstract goals and the low-level nodes are the more concrete immediate goals. The nodes are connected to other nodes by links. The attainment of goals can be affected by the attainment of lower-level goals and the links. Four link types consider in this model:

1. Sufficiency links can be considered in some degree sufficient to achieve the higher-level goal. It is necessary that one of them succeed. The degree is between 0 and 1.
2. Facilitative links increase in some degree the probability of higher-level goal attainment. The degree is between 0 and 1.
3. Inhibitory links decrease in some degree the probability of higher-level goal attainment. The degree is between 0 and 1.
4. Necessary links are necessary to some degree; however, none of them alone are sufficient. The degree is between 0 and 1 and the total of degrees must be 1. If we have many kinds of links, the Necessary links are computed first. In this study, we consider a minor effect for Facilitative and Inhibitory link. Hence, we select the degree between 0 and 0.3 for the Facilitative and between -0.3 and 0 for the Inhibitory. Major effect of these two links decreases the effect of Necessary links when lower attainment sub goals are connected by Necessary links to a higher goal. The selected range is adjustable in any domain by considering the effect degree.

We differentiate between root nodes (top goals) and the other nodes (sub goals). In the vectors *G* and *Goals*, we use only top goals. The attainment of a top goal is computed by considering the attainment of sub goals and link degree. We use a recursive method to compute the attainment. The method starts from leaves node (low level goals) and continues recursively to receive the root nodes by using Eq. 4. For example in the tutor example, we want to compute attainment of the top goals after occurrence of a sequence of events and actions by a student. The attainment computation of the lowest level goals on the leaves may need a function. This function concerns environmental variables with the goals. For example a student does the following sequence of events and actions: “Ask help”, “Ask help”, and “Correct Answer”. We have used a hypothetical attainment function in this example. The goal structure for a Mastery oriented student from (Jaques & Vicari, 2007) is used in Figure 2. The “Provide a correct response to the exercises” has attainment 1 and connected to “Have success in the activities” by sufficiency link. The attainment of “Have success in the activities” is 1*1=1. At the next level, the necessary links are assessed first. The attainment of “High effort” is 0.5*0.62=0.31 and “Receive appropriate help” is 0.5*0.8=0.4. The current attainment of a top goal like “Develop new skill” is 0.31+0.4=0.71. The “Ask for help” connect to “Develop new skill” with facilitative link and the attainment 0.76*0.3=0.228. In the basis of Eq. 4, the attainment of “Develop new skill” changed to 0.71+0.228*(1-0.71)=0.776. In this manner, “Have success in the activities” and “Finish the propose activity” affect the attainment of “Develop new skill”. The final attainment of “Develop new skill” is 0.82. The same process is repeated for “Improve level of competance” and “Learn new things”. So the corresponding row of “Correct Answer” in impact matrix is as follow:

$$\begin{array}{cccc} & \underline{\text{Develop new skill}} & \underline{\text{Improve level of competance}} & \underline{\text{Learn new things}} \\ \text{Correct Answer} & (\quad 0.82 & 0.82 & 0.82 \quad) \end{array}$$

The *Goals* and *G* vectors of the student's top goals are as follow:

$$Goals = \begin{pmatrix} \text{Develop new skill} \\ \text{Improve level of competance} \\ \text{Learn new things} \end{pmatrix}, G = \begin{pmatrix} 0.5 \\ 0.6 \\ 0.8 \end{pmatrix}$$

The desirability of “Correct Answer” based on Eq. 3 is 0.82:

$$Desirability(\text{"}Correct \quad Answer\text{"}) = \frac{0.5*0.82+0.6*0.82+0.8*0.82}{0.5+0.6+0.8} = \frac{1.558}{1.9} = 0.82$$

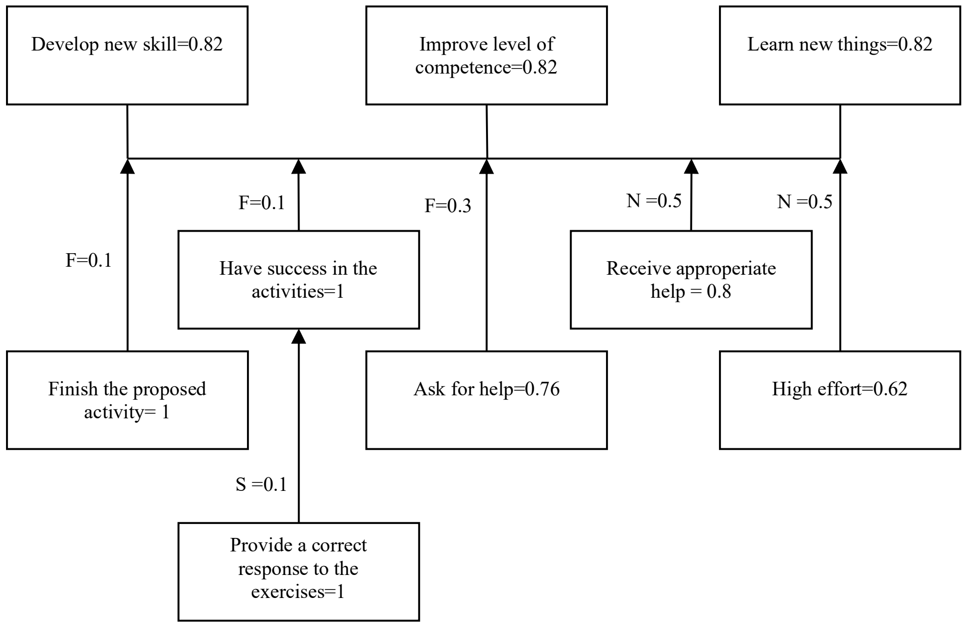

Figure 2: Goal structure of a mastery-oriented student

$$attainment(goal) = \begin{cases} attainment_1 + attainment_2 * (1 - attainment_1) & attainment_1 \geq 0 \quad and \quad attainment_2 \geq 0 \\ \dfrac{attainment_1 + attainment_2}{1 - \min\{|attainment_1|, |attainment_2|\}} & \begin{array}{l} attainment_1 \leq 0 \quad and \quad attainment_2 \geq 0 \\ attainment_1 \geq 0 \quad and \quad attainment_2 \leq 0 \end{array} \quad or \\ attainment_1 + attainment_2 * (1 + attainment_1) & attainment_1 \leq 0 \quad and \quad attainment_2 \leq 0 \end{cases} \tag{4}$$

We also use impact matrix to compute realization variable. The realization reflects the realized degree of a goal. The following formula is used to compute realization (Eq. 5):

$$\mathrm{Re}\, lization(e_i) = \frac{\sum_{j=1}^{n} \alpha_{ij}}{number \text{ of goals}} \tag{۵}$$
$$\forall j \in [1,n] and \forall i \in [1,m], \mathrm{Re}\, lization(e_i) \in [-1,1]$$

For the later example, the realization is 0.82.

3.2 Pattern Table

The expectedness of events and actions is computed in this element. This element uses a modified method in FLAME (El-Nasr et al., 2000). In this element, a probabilistic approach is used to learn sequence patterns of events and actions. The length of patterns can be between 2 and 7. In GEmA, we keep a table of pattern's counts, which is used to define the conditional probability. The repetition of each pattern increase pattern counter. These counts are used to calculate the expected probability of a new item (event or action) X_n occurring, given that the previous items X_1, X_2,…, X_{n-1} occurred ($0 \leq n \leq 6$). The expected probability of item X_n is calculated as follows (Eq. 6):

$$\text{Expectedness } (X_n) = \max (P_1, \ldots, P_{n+1}) \tag{6}$$

Where P_i is the probability of the pattern occurrence length i. The P_i formula is as follow (Eq. 7):

$$P_i = P(X_n \mid X_{n-1}, X_{n-2}, .., X_1) = \frac{\sum_{a_1,...,a_{n-i}} \text{Count}(a_1, ..., a_{n-i}, X_{n-i+1}, \ ... \ , X_n)}{\sum_{a_1,...,a_{n-i+1}} \text{Count}(a_1, ..., a_{n-i}, X_{n-i+1}, \ ... \ , X_{n-1}, a_n)} \tag{7}$$

Where a_i means, don't care the item X_i in this sequence. For n=3, we have the following probabilities (a_1=i, a_2=j, and a_3=j):

For i=1, $P_1 = P(X_3) = \frac{\sum_{i,j} \text{Count}(i, j, X_3)}{\sum_{i,j,k} \text{Count}(i, j, k)}$

For i=2, $P_2 = P(X_3 \mid X_2) = \frac{\sum_i \text{Count}(i, X_2, X_3)}{\sum_{i,j} \text{Count}(i, X_2, j)}$

For i=3, $P_3 = P(X_3 \mid X_1, X_2) = \frac{\sum \text{Count}(X_1, X_2, X_3)}{\sum_i \text{Count}(X_1, X_2, i)}$

For example, in the Virtual Tutor domain the following events and actions occurred by student:

"Ask Help", "Ask Help", "Correct Answer", "Ask Help", "Ask Help", "Correct Answer"

The length of patterns is 3 so we have the pattern table given in Table 1:

Table 1. Pattern Table (The length of patterns is 3)

Patterns	**count**
Ask Help, Ask Help, Correct Answer	2
Ask Help, Correct Answer, Ask Help	1
Correct Answer, Ask Help, Ask Help	1

The expectedness of a new "Ask Help" action is:

P("Ask Help")=0.67

P("Ask Help"| "Correct Answer")=1

P("Ask Help"| "Ask Help", "Correct Answer")=1

Expectedness ("Ask Help")=max (0.67, 1, 1) =1

We can see in the former sequence, which the expectedness of "Ask Help" gets 1 quickly after a few patterns occurrence. It is important to distinguish between expectation and probability (Dubs, 1942). Probability has to do with anticipated event and it is forward looking but expectation is assessed after an event and it is backward-looking (Ortony et al., 1988). It takes periods to grow the expectedness and unlike the probability dose not grow immediately after an event (action) occurrence. We consider an exponential distribution for expectedness (Price & Barrel, 1984; Price & Barrell, 1985). Hence, the expectedness grows smoother. The expectedness of the "Ask Help" action changed as follow:

P(“Ask Help”)=0.67

P(“Ask Help”| “Correct Answer”)=0.73

P(“Ask Help”| “Ask Help”, “Correct Answer”)=0.73

Expectedness(“Ask Help”)=max (0.67, 0.73, 0.73) =0.73

OCC uses unexpectedness in the emotions formula. The unexpectedness is equal 1-expectednss. The positive emotions use expectedness with power 0.5 and negative emotions use expectedness with power 2 (Price & Barrell, 1985).

3.3 Event and Action History

The event and action history table stores the occurrence of events and actions to compute their likelihood. In this study, we only compute the likelihood of occurrence of a desirable and an undesirable event. For example, in the Virtual Tutor domain the following sequence of events occurred by student:

“Correct answer”, “Correct answer”, “Correct answer”, “Wrong answer”

The likelihood of a desirable event is 0.75 (considered the “Correct answer” as a desirable event) and an undesirable event is 0.25 (considered the “Wrong answer” as an undesirable event).

3.4 Update the Intensity of Emotions

Ortony et al. (Ortony et al., 1988) consider emotions in three groups: goal-based emotions, standards-based emotions, and attitude-based emotions. In this study, we take into consideration sixteen of the OCC's twenty-two emotions. They are explained in detail in the following tables and sections. The goal-based emotions include two main classes: fortunes-of-others and fortunes-of-self. We represent fortunes-of-self class in this research. It contains eight goal-based (or event-triggered) emotions: joy, distress, hope, fear, satisfaction, disappointment, relief, and fear-confirmed (Table 2). The fortunes-of-others evaluates how the goals of others have been affected, goal successes or failures will generate four emotions: happy-for, sorry-for, resentment, and gloating, depending on whether the agent like or dislike the other agents. We leave this class for our future work. It needs a method to specify the liking/disliking. The standard-based (or action-triggered) emotions include four emotions: pride, shame, admiration, and reproach (Table 3). The composition of joy and distress from goal-based branch and standard-based emotions creates four new compound emotions (Table 4). The attitude-based emotions include love and hate. We need a method to calculate the appealing of objects to compute the intensity of love and hate. We leave it for our future work.

Table 2: Goal-based emotions (event-triggered emotions)

Status of event	Emotion	Explanation
Occurred	Joy	Occurrence of a desirable **event**
	Distress	Occurrence of an undesirable **event**
Unconfirmed	Hope	Prospect of a desirable **event**
	Fear	Prospect of an undesirable **event**
Confirmed	Satisfaction	**Confirmation** of the prospect of a desirable **event**
	Fear-confirmed	**Confirmation** of the prospect of an undesirable **event**

Disconfirmed	Disappointment	**Disconfirmation** of the prospect of a desirable **event**
	Relief	**Disconfirmation** of the prospect of an undesirable **event**

Table 3: Standard-based emotions (action-triggered emotions)

Based on action of	Emotion	Explanation
Agent	Pride	Action done by the **agent** and is **consistent with** standards of agents
	Shame	Action done by the **agent** and is **inconsistent with** standards of agents
Another agent	Admiration	Action done by **another agent** and is **consistent with** the standards of agents
	Reproach	Action is done by **another agent** and is **inconsistent with** the standards of agents

Table 4: Compound emotions

Emotion	Based on compound of		Explanation
	Goal-based emotion (event-triggered emotion)	Standard-based emotion (action-triggered emotion)	
Gratification	Joy	Pride	Joy + Pride
Gratitude	Joy	Admiration	Joy + Admiration
Remorse	Distress	Shame	Distress + Shame
Anger	Distress	Reproach	Distress + Reproach

Emotions can be updated by using OCC's general rule (Ortony et al., 1988). The general rule used for emotion *Joy* is as follows (Eq. 8):

$$\text{If } P_{joy}>T_{joy} \text{ Then } I_{joy}=P_{joy}-T_{joy}$$
$$\text{Else } I_{joy}=I_{joy}-\varepsilon \qquad (8)$$

In this rule, P_{joy} is the potential of emotion *joy* based on the outputs of the appraiser module, T_{joy} is the appearance threshold of emotion *joy* and I_{joy} is the intensity of *joy*. The threshold is determined by agent's personality, and the threshold is determined by correlation between emotion and personality. In GEmA, constant values are used for thresholds; because we couldn't find any model that implements emotion and personality correlation. However, our model is flexible to incorporate future developments.

The emotions in Eq. 8 decrease at each cycle with a decay parameter (ε). Some emotions fade immediately and some others remain longer (Mera & Ichimura, 2003). For example anger fades faster than relief. We use decay method in Mera and Ichimura (Mera & Ichimura, 2003) and a Poisson distribution is used for decay parameter (Eq. 9)

$$Decay(emotion_i) = \lambda_i e^{-\lambda_i t} \qquad \lambda_i \in [0,1] \qquad (9)$$

The λ_i of positive emotions differ from negative emotions. By trial and error, it is considered between 0.5 and 1 for positive emotions and 0.8 and 1 for negative emotions.

3.5 Computing the Potential Value

Some rules for computing the potential value of any emotion are given in the sequel; for these rules four OCC local variables and one OCC global variable are used. The unexpectedness is the global variable that affects all emotions. The local variables are desirability, praiseworthiness, likelihood, and realization. Rules are divided into three groups: goal-based rules, standard-based rules and compound rules. All rules are in the basis of OCC definitions (Ortony et al., 1988) and Price et al. (Price & Barrell, 1985) model is used for expectedness formulations.

3.5.1 Goal-based rules

In this group, the expectedness, likelihood and desirability are used. There are two sub-groups in this group. The first sub-group is as follows:

If	$D(e,t) \geq 0$	Then	P_{joy}	$= D(e,t) *(1-\alpha*\text{expectedness}(e)^{0.5})$
If	$D(e,t) < 0$	Then	$P_{distress}$	$= \lvert D(e,t) \rvert*(1-\alpha*\text{expectedness}(e)^{2})$
If	$D(e,t) \geq 0$	Then	P_{hope}	$= D(e,t) *\max(\text{expectedness}(e)^{0.5}, \text{likelihood}(e))$
If	$D(e,t) < 0$	Then	P_{fear}	$= \lvert D(e,t) \rvert*\max(\text{expectedness}(e)^{2}, \text{likelihood}(e))$

Where *D (e, t)* is the desirability of event *'e'* at time '*t*'; *likelihood(e)* is the occurrence probability of event *'e'*; *expectedness* is the expectedness occurrence of event *'e'*. *'α'* is the influence value of the expectedness. In our experiment, the best results obtained by α=0.5.

If agent has fear or hope emotion in time *'t'* then it is waiting for desirable or undesirable event occurrence on time *'t_2'*. The second sub-group emotions will be generated in time *'t_2'* by the following rules:

If	Confirm(e,t_2,hope)	Then	$P_{satisfaction}$	$=P_{hope}(t) *(\text{expectedness}(e)^{0.5}) *\lvert\text{realization}(e)\rvert$
If	Disconfirm(e,t_2,hope)	Then	$P_{disappointment}$	$=P_{hope}(t) *(\text{expectedness}(e)^{2})*\lvert 1- \text{realization}(e)\rvert$
If	Confirm(e,t_2,fear)	Then	$P_{fear\text{-}confirm}$	$=P_{fear}(t) *(\text{expectedness}(e)^{2})* \lvert 1- \text{realization}(e) \rvert$
If	Disconfirm(e,t_2,fear)	Then	P_{relief}	$=P_{fear}(t) *(\text{expectedness}(e)^{0.5})* \lvert \text{realization}(e) \rvert$

Where *Confirm(e, t_2,hope)* indicates the confirmation of the prospected desirable event *'e'* at $t_2>t$ where the emotion of agent was hope at time *'t'*; *Disconfirm(e, t_2, hope)* indicates the disconfirmation of the prospected desirable event *'e'* at $t_2 > t$ where the emotion of agent was hope at time *'t'*. It is the same for fear.

3.5.2 Standard-based rules

In this group, the expectedness and praiseworthiness are used. The rules are as follows:

If	Praiseworthiness(a,t) ≥ 0 and Own(a)	Then	P_{pride}	$=\text{Praiseworthiness}(a) *(1-\beta*\text{expectedness}(a)^{0.5})$

If	Praiseworthiness(a,t) < 0 and Own(a)	Then	P_{shame}	$=\lvert Praiseworthiness(a)\rvert * (1-\beta * expectedness(a)^{2})$
If	Praiseworthiness(a,t) ≥ 0 and not Own(a)	Then	$P_{admiration}$	$=Praiseworthiness(a) * (1-\beta * expectedness(a)^{0.5})$
If	Praiseworthiness(a,t) < 0 and not Own(a)	Then	$P_{reproach}$	$= \lvert Praiseworthiness(a)\rvert * (1-\beta * expectedness(a)^{2})$

Where *praiseworthiness (a)* indicates the praiseworthiness of action *'a'*. Own(a) indicates the agent that does the action and "not Own(a)" indicates another agent to do the action. 'β' is the influence value of the expectedness. In our experiment, the best results obtained by β= 0.5.

3.5.3 Compound rules

In this group, there are four emotions. Each compound emotion is a blend of two emotions. Silverman stated the following rules for this group (Silverman, 2001):

if $abs(I_{pride}-I_{joy}) \leq 0.2$	$P_{gratification}$	$= Max(I_{pride},I_{joy})$
if $abs(I_{admiration}-I_{joy}) \leq 0.2$	$P_{gratitude}$	$= Max(I_{admiration},I_{joy})$
if $abs(I_{shame}-I_{distress}) \leq 0.2$	$P_{remorse}$	$= Max(I_{shame},I_{distress})$
if $abs(I_{reproach}-I_{distress}) \leq 0.2$	P_{anger}	$= Max(I_{reproach},I_{distress})$

Since emotions decay over time, they exist at different intensities over time. Hence, the gratification emotion, for example, exists while the absolute value of the difference between intensities of joy and pride is lower or equal to 0.2 at any time.

4 GEmA Library

We implemented the GEmA as a programming language library with Microsoft C# and JAVA[1]. The library includes four parts as follow:

Emotion Modeling implements two classes: Emotion and EmotionalCharacter. The Emotion class implements goal-based rules, standard-based rules, compound rules, "update the intensity of emotions", and "decay intensity of emotions". EmotionalCharacter is an abstract class. The users must inherit this class to implement their emotional agents. This abstract class includes a goal, a standard, and an event and action container. It also includes a pattern table, a handler for events and actions and an implementation of the event and action appraiser to compute desirability and praiseworthiness. The class diagram of this part is showed in Figure 3.

[1] This libraries are downloadable from http://www.appliedemotion.com

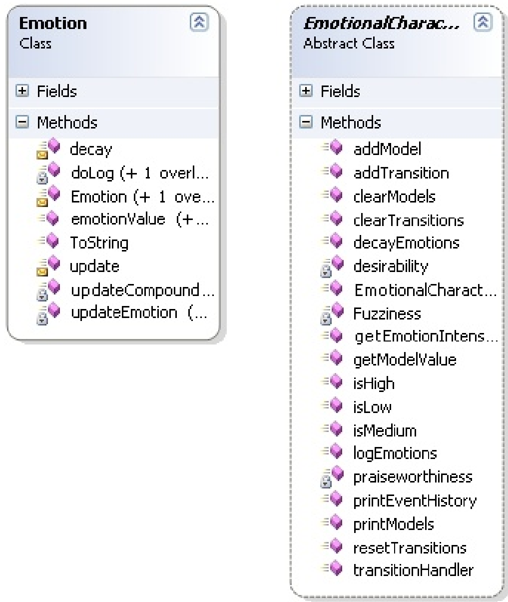

Figure 3. The class diagram of emotion modeling

Mind Modeling implements three classes: Model, TopModel, and ModelLink. These classes implement the macrostructure of goals and standards. They also implement the calculation of events impact and actions impact on goals and standard by using the former method in section 3.1. The class diagram of this part is showed in Figure 4.

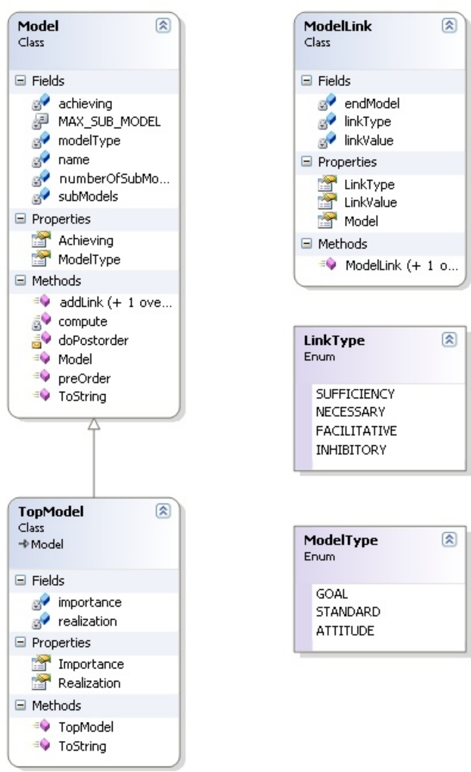

Figure 4: The class diagram of mind modeling

Pattern Modeling implements the pattern table of section 3.2 to compute the expectedness of an event or action. It includes two classes: Pattern, which implements the properties and functionality of each pattern and PatternTable, which implements a table of Patterns. The class diagram of this part is showed in Figure5.

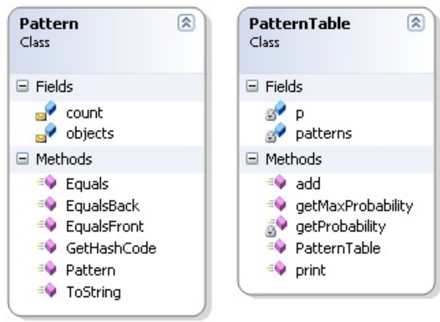

Figure5: The class diagram of pattern modeling

Transition Modeling implements the properties and functionality of events and actions. It includes three classes: Transition, Event, and Action. The class diagram of this part is showed in Figure 6.

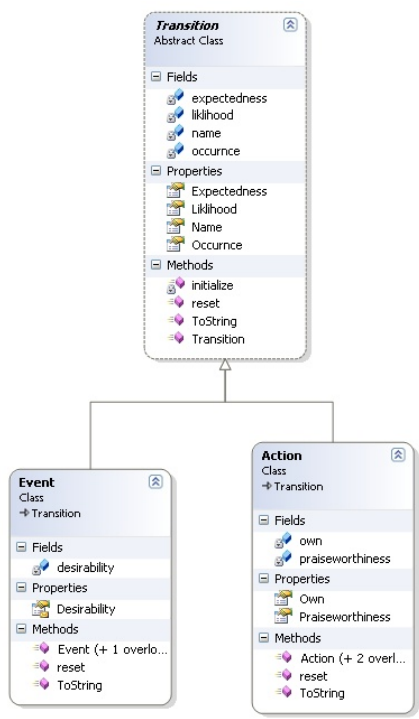

Figure 6: The class diagram of transition modeling

5 GEmA's Implementation

Learning and tutoring involve emotional processes. Some of these emotions sit in the way of the learning process. Emotions are used to master a practice or to learn a theory. In building a virtual tutor system we should avoid negative emotions that arise in the learning process and we should implement ways to generate positive emotions (Poel et al., 2004). In this domain, we only consider the role of emotions in learning. Many other appraisal variables, like controllability, dominance, and coping potential, must be considered in a comprehensive learning system (Gratch & Marsella, 2004).

In this system, there is an emotional Virtual Tutor which uses GEmA to simulate student's emotions. To provide data to GEmA, two goals have been considered for students (Ames, 1990). Hence, we have two types of students:

1. Students who are interested in learning new things, developing their skills, and increasing their abilities have been described as *mastery oriented* (Ames, 1990).
2. Students who perceive that normative performance is important and want to demonstrate their abilities have been described as *performance oriented* (Ames, 1990).

In order to identify the importance of goals of the students, we use the *Motivated Strategies for Learning Questionnaire (MSLQ)* (Pintrich, 1991). The MSLQ is a self-report instrument, which allows determining students' motivational orientation and learning strategies. We use a shorten form of MSLQ received from Jaques (Jaques, 2004). It contains eight questions; four for Mastery goals and four for performance goals. Virtual Tutor gets and stores the goals via a form showed in Figure **7**.

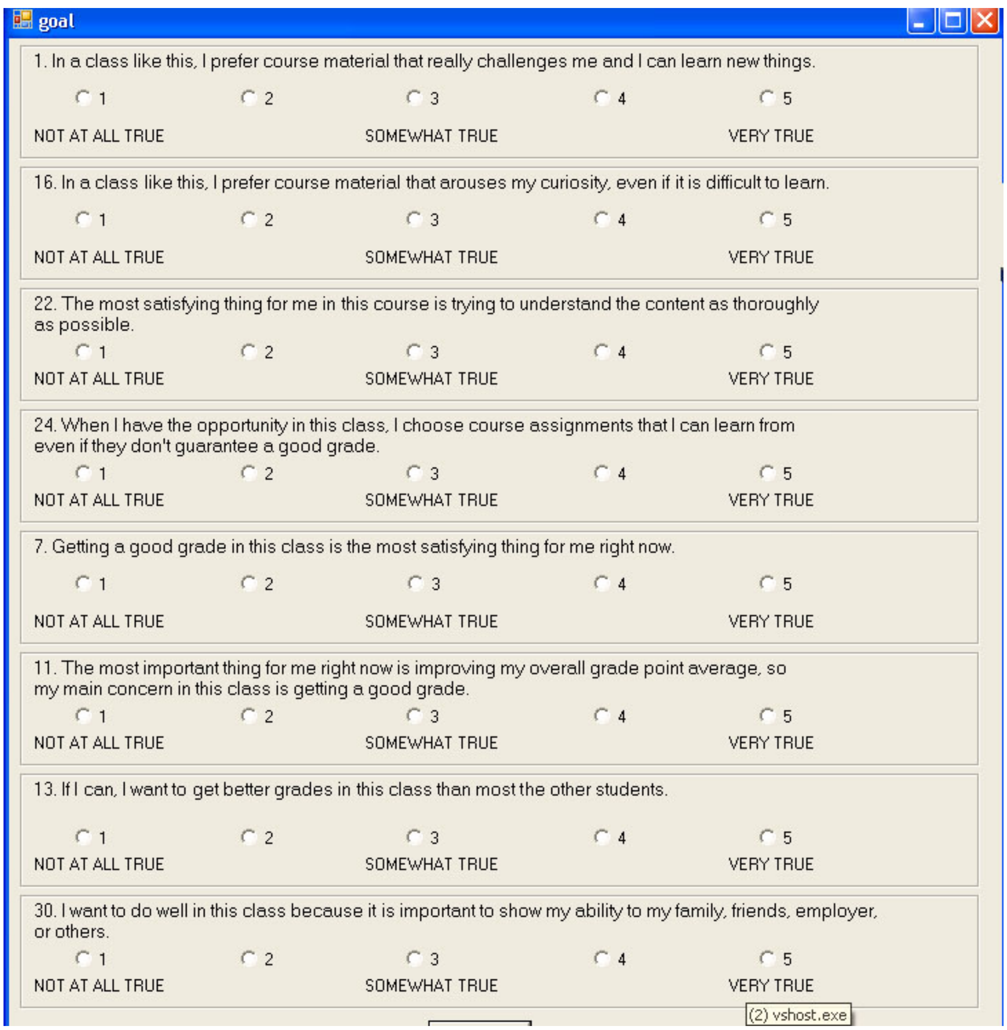

Figure 7: Goal screen to get student's goal. The first foursome is for mastery and second foursome is for performance goal.

Virtual Tutor uses some educational tactics to respond to the actions of the students. Each tactic includes the following goals (Jaques, 2004; Jaques & Vicari, 2007; Zhou, 1999):

1. Increase student's self-confidence
2. Increase student's effort
3. Offer help to student
4. Encourage student
5. Increase student's interest to subject

Three fuzzy sets are used to describe emotion's intensity; which are low, medium and high. Figure 8 depicts fuzzy sets on emotions. The Virtual Tutor system uses emotions to select educational tactics. The rules of selecting educational tactics acquired from (Jaques, 2004) and adopted to match with GEmA. There are twenty rules to select eighteen educational tactics. The adaptations of rules of Jaques (Jaques, 2004) for GEmA is done in the following ways:

1. The rules were qualitative. We have quantified and also fuzzified them (Figure 8).
2. It did not include hope, fear, remorse, and gratification emotion. We have included these emotions in the rules.
3. They were distinguished for mastery oriented and performance oriented student. We have transformed them into general rules for both types of students. The students' goals affect the intensity of emotions. Hence, the intensity of emotions as well as educational tactics are different for students by different goals in the same situation.

A sample education tactic rule of our Virtual Tutor is as follow:

Rule1:	IF	(	Distress	IS	High
		OR	Shame	IS	High
		OR	Remorse	IS	High
		)		IS	
		AND	Student's Action	IS	Wrong Answer
	THEN		Tactic1	IS	Recognize-student-effort
		AND	Tactic2	IS	Need-Help

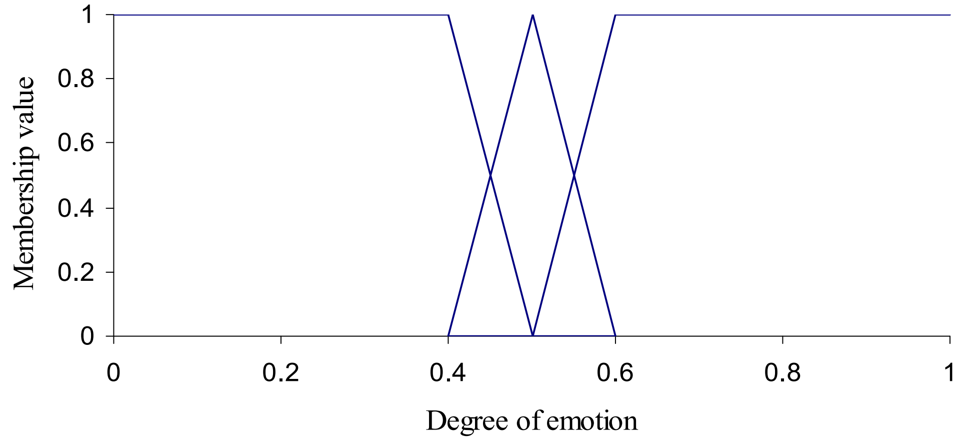

Figure 8: Fuzzy sets of emotions

Each educational tactic contains two emotional behaviors: physical and verbal. Our Virtual Tutor uses gesture and facial expression to show physical behavior and speech and emotional text to show verbal behavior. For this purpose, Microsoft Agents are used. They have the ability of show text, text to speech and emotional actions. The appropriate emotional actions and speech for Microsoft Agents are got from (Zong, Dohi, & Ishizuka, 2000).

English learning domain is used for the Virtual Tutor. The implementation is done in Microsoft Visual Studio environment and C# language. Microsoft SQL Server was used for educational tactics database. It includes ten events as well as two actions. A sample of the environment is showed in Figure 9. Because of the decay parameter in emotion fading, several emotions exist in the same time.

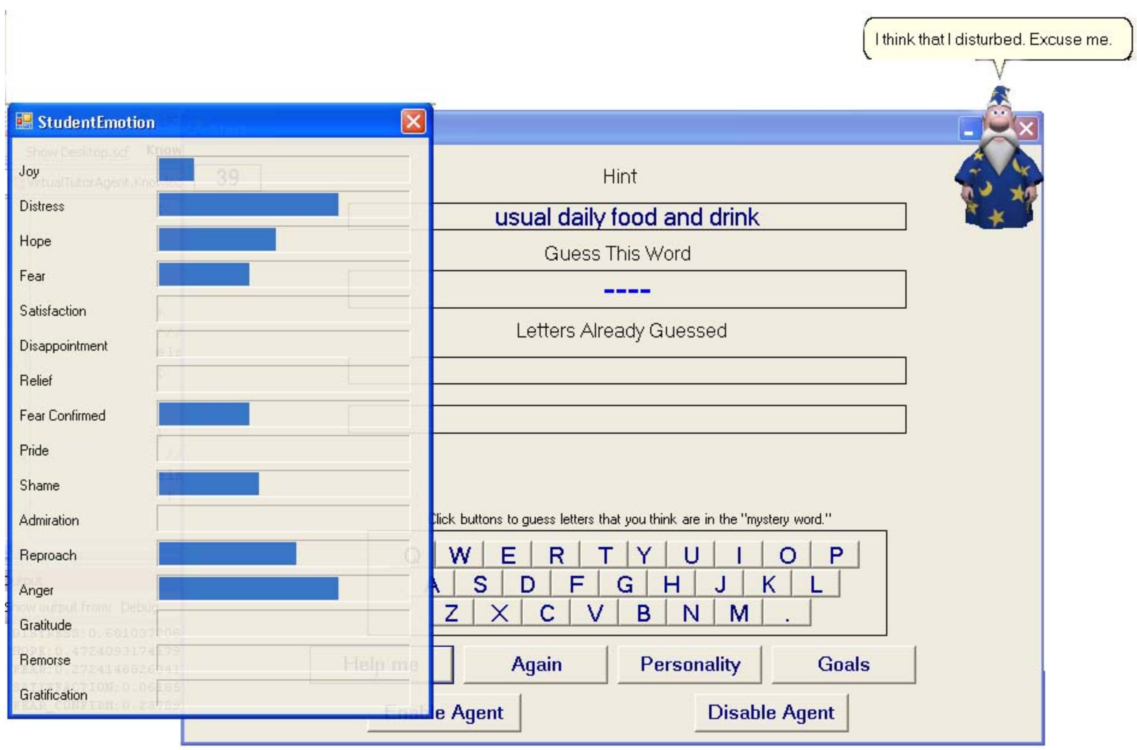

Figure 9: Virtual Tutor environment

In the evaluation, we chose user assessment method. Users worked with the system and then the feedback was gathered via a questionnaire. The reasons for using questionnaires as evaluation method are (El-Nasr et al., 2000):

1. Structured answers of user to the target questions.
2. Ordinary users can use questionnaires, as opposed to requesting more sophisticated feedback from experts.
3. Comparing the performance of the system to a real one under the same experimental conditions is not convenient.

Two evaluations with two different groups of users have been done. In the first evaluation, we evaluate the believability of the emotional Virtual Tutor using GEmA as its emotion engine and in the second one; we evaluate the accuracy of the GEmA.

5.1 Believability evaluation of Virtual Tutor

In the first evaluation, the system was evaluated with thirty Iranian computer science students, ages between 20 to 25. The English of all these students were elementary. They worked with the system in two modes: firstly without virtual tutor (mode_1), secondly with emotional virtual tutor (mode_2). The goals of the users are received by Figure **7** and stored in database for further processing by GEmA. Figure 10 shows the average satisfaction of users in two modes. In mode_1, the satisfaction of users is: 50% medium, and 3.33% high. In mode_2, the satisfaction of users is: 33.33% medium, 41% high and16.67% very high.

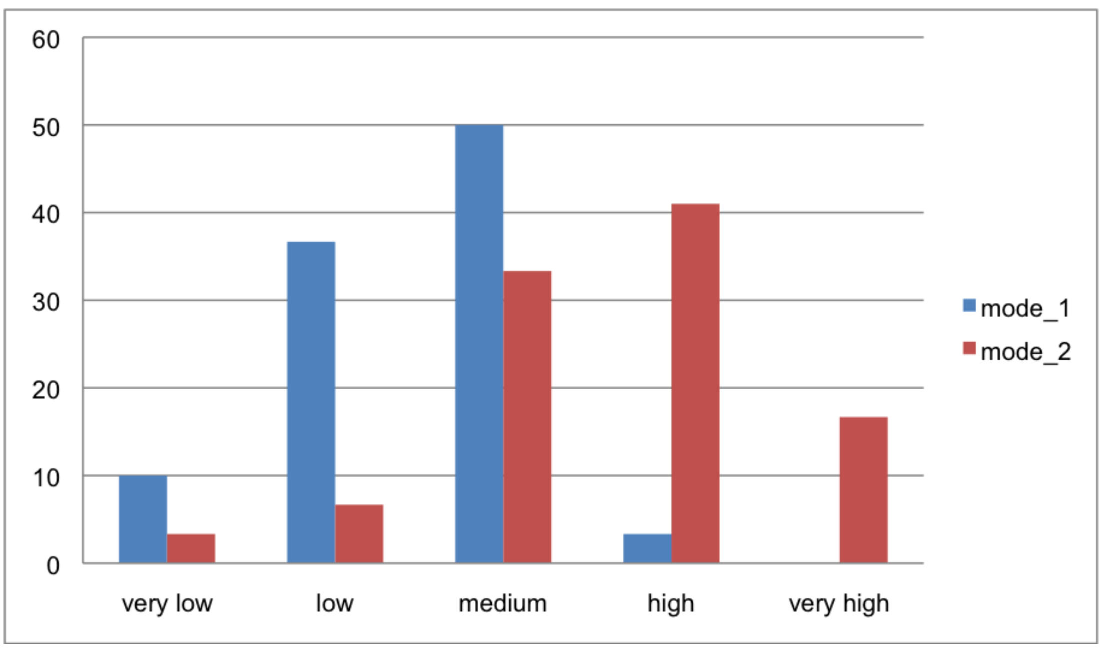

Figure 10: Comparison of satisfaction in two modes of system:
without virtual tutor (mode_1) and with virtual tutor (mode_2)

Since users with different goals in the same situation have different emotional states, the Virtual Tutor performs different educational tactics for them. The Virtual Tutor uses Microsoft Agents to perform its educational tactics. We evaluate the believability of emotional behaviors of Virtual Tutor in performing educational tactics by the following question:

How well does the virtual tutor show its emotions? (Figure 11)

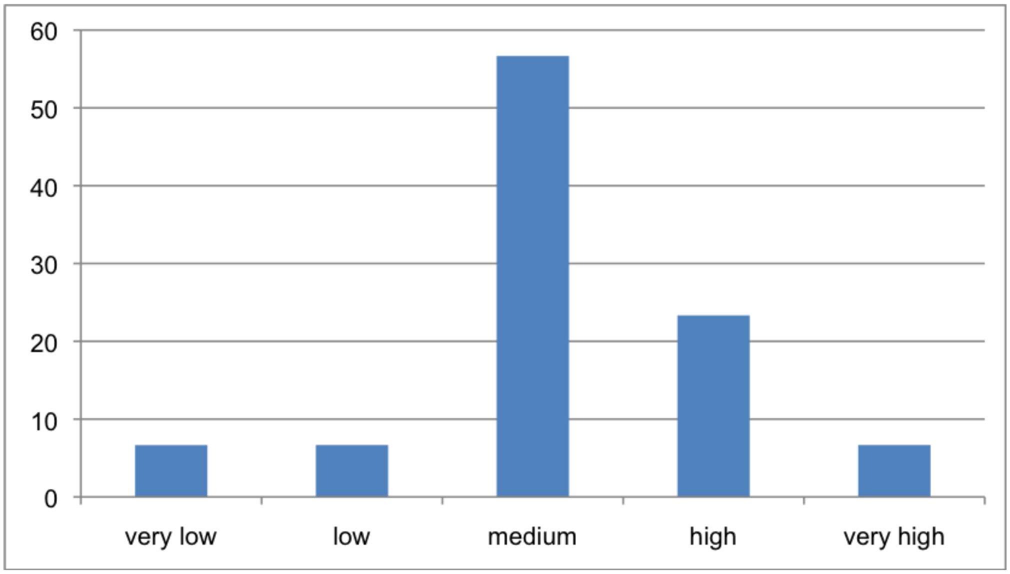

Figure 11: The evaluation of the emotions of the virtual tutor

5.2 Accuracy of GEmA

In the second evaluation, the accuracy of GEmA was evaluated with twenty volunteers, with an average age of 23. The Virtual Tutor was not emotional and only could help the users. Before starting the evaluation, the user was given an introduction to the system and the evaluation method. The user was asked to report only the emotions in interactions with this system not other external emotions.

Users were asked to fill the form presented in Figure 7. Then, they were to go through the system and report their emotions while interacting. After the occurrence of each event (or action of users), a screen is opened and the users report their event-triggered and compound (or action-triggered) emotions on six levels: no emotion, very low, low, medium, high, very high (Figure 12 – right screen). After that, on the other screen, the intensity of emotions simulated by GEmA is shown to the users to be evaluated by them according to a scale ranging from 0-100 (Figure 12 – left screen). All interactions of the users log into files for further processing and research[1]. The average rating was 60.

[1] All the data are available to other researchers for further research.

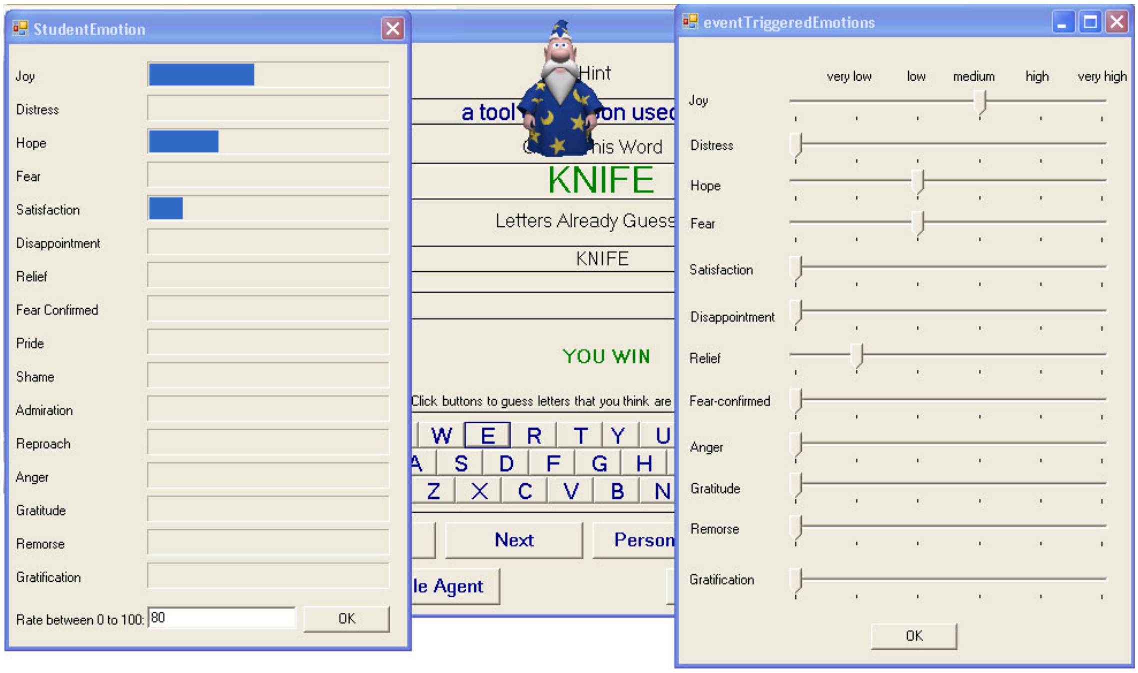

Figure 12: The left screen for rating simulated emotions
and the right screen for reporting event-oriented and compound oriented emotions

The accuracy of GEmA was evaluated after the test by processing the logs. To cover the inaccuracy of users in reporting the intensity of their emotions, we mapped the intensity of emotions in the logs and GEmA on three levels: low, medium, and high. The comparison of the GEmA results according to the reported emotions is stated in Table 5.

Table 5: The evaluation result of GEmA accuracy

	Joy	Distress	Hope	Fear	Satisfaction	Disappointment	Relief	Fear-Confirmed	Pride	Shame	Admiration	Reproach	Anger	Gratitude	Remorse	Gratification
Percent of accuracy	61	65	60	74	51	70	56	87	79	46	60	48	71	63	66	47

In this experiment, we evaluated the emotions of the users via many forms and items. By this method, the reported emotions may have been affected by some negative emotions (i.e. anger) related to the method itself. This is one of the limitations of this method.

6 Conclusion

In this research, a new generic emotional model of emotional agents (GEmA: Generic Emotional Agent) is introduced. The main goal of GEmA involves emotions as a module in decision making by agents so that an agent can behave similar to humans. Also, a new computational method is offered which is based upon the evaluation of events and actions.

With respect to the goals and standards of the agent, the computational rules are used to map the impact of events and actions on emotional states. This method is flexible and adaptable to different environments; and can be utilized as a separate module in advanced applications. The GEmA is open source and the users can adjust the parameters of the GEmA to their particular needs. The generic emotional model is implemented in the Virtual Tutor domain to show adaptability.

In our future work, we aim to perform experiments on more complex situations and to include *personality* as well as *motivation* and *mood* states for computations. Lack of data, the misconception of users about the definitions of emotions as well as the unawareness of users about their emotions are some of the hindrances in our work. The GEmA can be tested with more data and more accurate methods in the future. Finding a suitable goal attainment function for leaf nodes in the goal hierarchy is a design issue in any program using GEmA. Finding a method to select a suitable function is another work for future.

In this article we focused on only sixteen of twenty-two emotions of the OCC model. We used a number of the emotions of the goal-based group and all the emotions of the standard-based group. In the future, the attitude-based group and the other emotions in the goal-based group and the impact of other OCC parameters will be assessed in computations. As long-term goals, we are interested in exploring the effects of personality and culture in decision-making.

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