Emotionally Intelligent Tutoring Systems (EITS)

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Abstract

It is well-known that emotions have a strong influence on a person's cognitive abilities; a fact which can be used by a tutor to improve a student's learning capacities. Conditions are that the tutor knows the current emotional state of the learner as well as the emotional impact of certain actions taken and, finally, how the student's learning capacities depend on his emotions.

In this article, we propose the concept of an *Emotionally Intelligent Tutoring System (EITS)* and make a step towards its practical realization: We develop a tool allowing an Intelligent Tutoring System for improving a learner's capacities by actively influencing his emotions. More specifically, we combine Case-Based Reasoning methods with graph knowledge representation for modeling and predicting efficiently a learner's emotional reaction to specific situations which can occur during a learning lesson, with the final objective of promoting any particular users learning capacities.

Motivation and Introduction

Emotional Intelligence

Emotional intelligence is a form of intelligence providing the capacity to monitor one's own and other's emotions, and to use it to guide one's thinking and actions. The concept of emotional intelligence is based on to the relation between "thinking" and "feeling". Indeed, emotions are narrowly linked to the cognitive process. Without emotions, we are unable to make even the simplest decision (Damasio 1995). Moreover, some strong emotions, like anger or anxiety, can prevent us from concentrating on our every day tasks (Goleman 1997). People who have positive emotions will think in a more creative, expansive, and divergent way. On the other hand, negative emotions will more likely lead to a conservative, linear, and sequential thought process (Lisetti & Schiano 2000). In particular, being emotionally intelligent means to act in a way that takes into account someone's emotions in order to improve his cognitive abilities. In schools, teachers should be emotionally intelligent to improve students learning capacities. Similarly, Intelligent Tutoring Systems (ITS) should integrate emotional intelligence for improving the learner's performance.

Emotionally Intelligent Tutoring Systems (EITS)

Giving emotional intelligence to a computing system means enabling it to determine a person's emotional reactions, i.e., to anticipate how his emotions will vary in given situations. Recently, some systems have been proposed for modeling a generic learner's emotional reactions in interaction with an ITS. For instance, Abou-Jaoude and Frasson (1999) have developed a computational matrix to compute and constantly update learner's emotions. At the MIT Media laboratory, works are under way to create an "affective learning companion" which adapts to the user, for instance by adjusting the difficulty of an exercise (Picard, Kort & Reilly, 2002). The main drawback of most previous approaches is that they are based on a model of a *generic* learner's emotional reactions. However, emotional experience is a complex process which depends on each person and each situation (Hess, 2001). In order to integrate this human variability we propose an *individualized* system able to predict the emotional reaction of each specific learner in various situations. This system, called *Case Based Emotioning System* (CBE), uses a Case Based Reasoning method to model a learner's emotional reactions.

We give an outline of the rest of the paper. We first describe how to represent and assess the learner's emotions. We then give the architecture of the CBE System and subsequently describe its different components. Finally, we give some experimental results.

Towards Realizing Emotionally Intelligent Tutoring Systems

Quantifying and Measuring Emotional States

Currently, there is no consensual definition of the concept of emotions. For instance, there are more than 600 terms which refer to emotions. In our work, the learner's emotions felt at a given moment are represented by his *emotional state*, which we represent – based on (Ortony, Clore & Collins, 1988) – with respect to nine antipodal emotional couples (E_{i1}, E_{i2}) shown in Figure 1.

(E_{11}, E_{12})	Distress vs Joy
(E_{21}, E_{22})	Disappointment vs Relief
(E_{31}, E_{32})	Anxious vs Confident
(E_{41}, E_{42})	Boredom vs Intrigue
(E_{51}, E_{52})	Self-reproach vs Pride
(E_{61}, E_{62})	Reproach vs Appreciation
(E_{71}, E_{72})	Resentment vs Sorry-for
(E_{81}, E_{82})	Anger vs Gratitude
(E_{91}, E_{92})	Remorse vs Self gratification

Figure 1: Antipodal Emotional Couples

The value e_i with respect to the emotional couple (E_{i1}, E_{i2}) is a real number which varies between –1 and +1 inclusively. The values –1 and +1 indicate that the emotion on the left and right hand side, respectively, of the couple is being experienced to the maximum. The value zero indicates that no emotion of the couple is currently being felt. The emotional state E of a learner is thus represented by a vector of nine values: $E=(e_1, e_2, \ldots, e_9)$.

To determine the emotional state of a learner, we use nine *emotional scales* (Figure 2), into which the learner enters his current state by positioning the cursors. Based on some work about the classification of emotional terms (Ortony, Clore & Collins 1988) (Kort, Reilly & Picard 2001), we have graduated each emotional scale with different adjectives to make the learner's evaluation of his emotions more intuitive.

Predicting Emotional Reactions: The Case Based Emotioning System (CBE)

Emotions are present in any form of education: learners worry, hope, become bored, embarrassed, envy, get anxious, feel proud, become frustrated, and so on. Teaching in traditional contexts can be viewed as an emotional practice in which the emotional practitioners, like the teachers, can lead a person to feeling specific emotions by using different behaviors and actions (Hargreaves, 2000). Similarly, pedagogical agents, such as tutors in an ITS, are emotional practitioners. Moreover, recent research has shown that people display a natural propensity for interacting with machines as if they were other humans (Picard, 1997). These facts serve as a motivation for exploiting the emotional control of a pedagogical agent for the benefit of learning efficiency.

Recent research has shown that whereas certain emotions reduce our capacity to learn, others improve it (Goleman 1997) (Klein, Youngme & Picard 2002) (Lisetti & Schiano 2000) (Keller 1987). The problem of determining the best emotional learning state of a specific learner is subject to ongoing research.

We propose a tool, called Case Based Emotioning System (CBE), enabling any ITS to control the learner's emotions. The CBE system predicts the emotional reaction of a learner in given situations which can occur during a learning session in ITS, and is able to propose a particular situation in order to change the learner's current emotions to another. To create this system, we use a problem solving methodology known as Case Based Reasoning (CBR). The main idea of CBR is to solve new problems by using solutions of cases stored in a library – this allows for finding a solution to a new problem for which no algorithm is known. However, the emotional process of a person is very complex and we cannot define an algorithm to determine the emotional reactions of a person in any case. The CBR allows making predictions based on experienced situations (cases) without having a complete understanding of the domain (Kolodner, 1993). Our system is composed of four modules (Figure 3) and predicts emotional reactions using an emotional reaction database: the *Emotional Cases Library* constructed by the *Emotional Simulator*. This module will ask the learner to evaluate his emotional reaction to several situations from the *Situations' Library*. Whenever a new problem occurs, the *Retrieval Module* searches the Emotional Cases Library for a solution to solve it.

Modeling Emotional Reactions: The Emotional Cases Library

The basis of CBR is a collection of cases representing knowledge, each with respect to a particular situation (Kolodner 1993). In our system, the knowledge we represent is how a person's emotional reaction depends on an occurring situation and the current emotional state. The initial state is an important parameter in this context. Indeed, someone's emotion depends on the appraisal of a situation (Ortony, Clore & Collins 1988), while, on the other hand, the appraisal of the situation depends on the emotional state at the time the situation occurs (Lisetti & Schiano 2000).

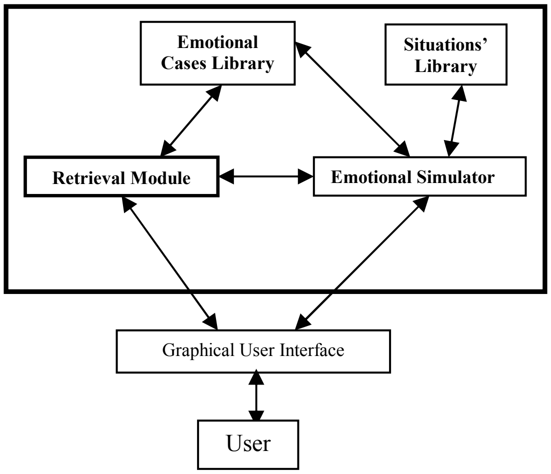

Figure 3: Architecture of the CBE System

We hence represent an emotional reaction by the triplet <Current Emotional State E, Specific Situation S, Resulting Emotional State E'> representing the fact that if the learner is in the emotional state E, then given the situation S he will be in the emotional state E'.

A case indicates how to resolve a similar situation in the future and can hence be seen as a solved problem. Given such an emotional case <E, S, E'> we are able to solve two sorts of problems:

What will the emotional state of the learner be in the situation S if he is in the emotional state E? The solution is E'.

How to modify the emotional state E to E'? The solution is S (or "putting the learner in the situation S").

In summary, emotional cases will allow us to determine the emotional reaction of a learner in specific situations and moreover how to change the learner's emotional state to another.

The collected emotional cases are stored in a cases library, which – given the structure of a case – we can represent as a directed graph, the vertices and edges of which are labeled (Champin & Solnon 2003). More precisely, a vertex is labeled with an emotional state and an edge with a specific situation; an edge labeled with S and connecting the vertices labeled by the emotional states E and E', respectively, represents the case <E,S,E'>.

More formally, given a set of vertex labels L_v and a set of edge labels L_e, a labeled directed graph is a triple $G=(V, r_v, r_e)$ such that:

V is a set of vertices,

$r_v \subseteq V{*}L_v$ is the relation that associates vertices with labels: r_v is the set of couples (v_i,E) such that vertex v_i has label E,

$r_e \subseteq V{*}V{*}L_e$ is the relation that associates edges with labels: r_e is the set of triples (vi, vj, S) such as the edge (vi,vj) has label S.

The advantage of this graph representation is the possibility to easily create compositions of cases. For example, the two cases $<E_1,S_1,E_1'>$ and $<E_2,S_2,E_2'>$, where $E_1' = E_2$ holds, can be composed and are represented in the graph as shown in Figure 4.

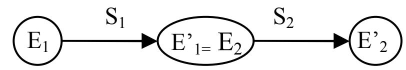

Figure 4: Example of Emotional Cases Graph Representation

Therefore, the larger space, including the combined cases, is $\{<E_1,S_1,E_1'>, <E_2,S_2,E_2'>, <E_1, S_1{:}S_2,E_2'>\}$, where "$S_1{:}S_2$" represents the temporal sequence of situations: first S_1, then S_2.

In the context of problem solving, a larger space of cases means that we can solve more problems to find a solution.

Retrieving Cases from the Emotional Cases Library: The Retrieval Module

CBR methods solve new problems using solutions of cases stored in the cases library. When a new problem arises, the system retrieves the cases the solutions of which are relevant for the new problem (Kolodner 1993).

Our system solves two sorts of problems, each requiring a different retrieval algorithm. First, the CBE system is able to determine what the emotional reaction of a learner will be in a specific situation S given his current emotional state E (which the learner will enter using the emotional scales (Figure 2)). The new problem is therefore defined by an emotional state E and a specific situation S. We will represent it by the couple (E, S). The solution is an emotional state E'. After retrieving the case(s) relevant to the new problem, the Retrieval Module derives the solution from these old cases by using some adaptation algorithm. A (simple) example of such an algorithm is to search the vertex v labeled with the emotional state that closest – with respect to the Euclidean distance – to the initial state E of the new problem and such that there exists an edge e=(v,v') labeled by S; the solution E' is then the label of v'.

The second type of tasks the CBE system is able to do is to suggest specific situations which will change the current emotional state E of the learner to the emotional state E' that is best for learning. This task is defined by a current emotional state E (entered by the learner using the emotions scales) and the target state E' (that we suppose to be known). We will represent it by the couple (E, E'). The solution is a temporal sequence of specific situations $\{S_1 : S_2 : \ldots : S_n\}$ $(n \geq 1)$. A simple example of an adaptation algorithm for this problem would be to search the cases library for the vertices labeled by emotional states closest to E and E', respectively, and to determine a path of minimum length connecting these two vertices. The sequence of the situations labeling the edges in this path is the output of the algorithm.

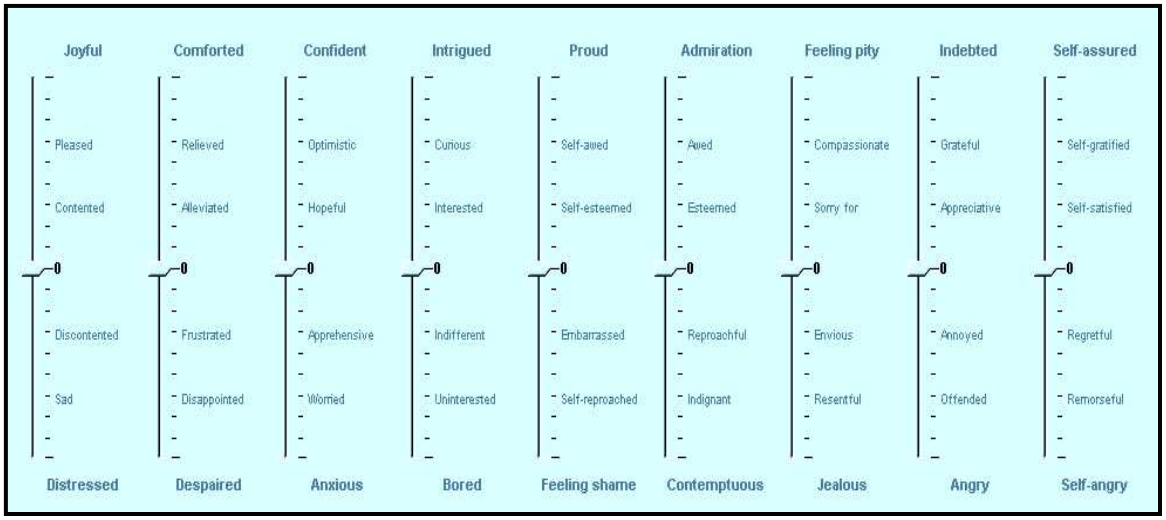

Figure 2: Emotional scales

Construction of the Emotional Cases Library: The Emotional Simulator

The initialization of the Emotional Cases Library is done by a tool called Emotional Simulator, which determines the emotional reaction of a learner in different specific situations. For implementing such an Emotional Simulator, we have first defined a set of situations that can occur in an ITS employing different possible pedagogical strategies. A situation depends on the actions of pedagogical agents and on the learning environment which is composed of different actors. For example, the actions of a tutor are to criticize, encourage, felicitate, give good or bad advice, ask questions, and so on. It is important to note that the effect of a certain action taken depends on the specific (learning) environment and context. For example, in the classical tutor strategy the learning environment is composed of the learner and the tutor; in the troublemaker strategy the learning environment is composed of a troublemaker, a tutor, and a learner. Moreover, the action of each pedagogical agent can be directed to the learner or to another pedagogical agent (a companion, a troublemaker,…). We hence represent a situation by the quadruple: <Environment e_v, Action a, Agent actor a_c, Action's recipient r>, where e_v is the set of agents in the learning environment and a is the action performed by the agent a_c ($a_c \in e_v$) and directed to r (the learner or an agent that belongs to e_v). For example, the situation "The tutor criticizes the troublemaker" is represented by the quadruple <{Tutor t, Learner l, Troublemaker m}, criticize, Tutor t, Troublemaker m >.

We associate each of these situations to a similar situation in a professional context. For example, the situation where the tutor criticizes the learner in front of a group of unknown people can be similar to a situation where a superior criticizes the learner in a meeting with a group of unknown people. This way we end up with a set of situations from a professional context and more familiar to the learner than the corresponding ITS situations. We have built a database of couples of situations (s_{i1}, s_{i2}), where s_{i1} is a specific situation in an ITS context and s_{i2} is a similar situation in a professional context.

New cases will be constructed according to the current emotional state of the learner. First of all, when the emotional simulator is triggered, it asks the learner to enter his current emotional state with the emotional scales (Figure 2). Then, the emotional simulator presents successively the professional situation s_{i2} for each couple (s_{i1}, s_{i2}) of the situations' database. It asks the learner to imagine what his emotional state E' would be in each situation. The emotional simulator can then create a new case <E, s_{i1}, E'> and inserts it in the emotional cases library.

Experimental Results

We have implemented the Emotional Simulator and the Retrieval Module of the proposed system in order to test its validity. We then carried out an experiment involving a group of people. In a first phase, the Emotional Simulator asked each participant to enter his present emotional state, and then to imagine a number of situations and project his resulting emotional state in each case.

In the second phase, the Emotional Cases Library that had been constructed for each participant in the first phase was accessed by a Retrieval Module with the objective of solving new cases.

Although only simple adaptation algorithms were used in this pilot test, the predictions made by the Retrieval Module turned out to be highly accurate.

Concluding Remarks

In the context of learning in general – and of intelligent tutoring systems in particular – the learner's emotions are of paramount importance. As a novel paradigm, we propose Emotionally Intelligent Tutoring Systems (EITS) which take this fact into account and use it for the learner's benefit.

In particular, we have developed a tool, called The Case Based Emotioning System, enabling an ITS to manage these emotions. More precisely, this system is able to predict for a given learner his emotional reactions in several situations. It can furthermore suggest which situations to use in order to change the learner's emotional state to another.

Our future objective is to integrate the CBE system into an ITS in order to assist pedagogical agents in their actions, improve the learner's performances, and hereby create an EITS.

Acknowledgments

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