Pat: an Pedagogical and Affective Tutor

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Abstract. *This paper presents the architecture of a lifelike and emotional pedagogical agent, called Pat, which has the goal of inferring the student's emotions and applying affective tactics in order to adapt the educational environment to the student's emotions, motivate him and promote a positive mood into the student, which fosters learning. Pat attempts to promote more positive feelings into the student by presenting emotional animated attitudes and encouragement messages which are chosen dynamically to compose its affective tactics. In order to accomplish this goal, its architecture is composed by two main modules: the brain that is responsible for inferring student's emotions and choosing the affective tactics, and the body that, given a affective tactic sent by the mind, selects and present dynamically the attitudes and speech that compose it. This paper also presents an evaluation of Pat's affective tactics accomplished by teachers and pedagogues.*

1. Introduction

Due to their motivational potential, many educational systems have been implemented as animated pedagogical agents (André, Rist, & Muller, 1999; Lester, Towns, & Fitzgerald, 1999; Paiva, Machado, & Martinho, 1999). The animated pedagogical agents are pedagogical agents, intelligent agents that have an educational or pedagogical role to facilitate or improve learning (Gürer, 1998), that use multimedia resources to provide the student with a lifelike character with characteristics similar to ones of intelligent alive creatures. These characteristics, such as facial expressions, gestures and understanding of human emotions, with a dialogue-driven user interface, make the agents more attractive to the students since they explore lifelike modes of interaction. The animated pedagogical agents offer great promise for increasing the communication capacity of the educational systems and increasing the ability of these systems to engage and to motivate the students (Elliott, Rickel, & Lester, 1999; Lester et al., 1999).

On the other hand, the way that emotions affect learning had already been pointed out by psychologists and pedagogues (Goleman, 1995; Piaget, 1989). According to Piaget (Piaget, 1989), the accelerating or perturbing role of affectivity in learning is incontestable. A good portion of the students that are weak in mathematics fails due to an affective blockage (Piaget, 1989). Izard's works (Izard, 1994) shows that

induced negative emotions in a person show to impair performance on cognitive tasks, and positive emotions have an opposite effect.

Based on these studies, we are working on making learning environments more pedagogically effective by making them capable of promoting positive emotions into the student, motivating him, and stimulating his learning. Although there is an evident progress in recent years to provide answers on constructing computer-based educational tools, very little attention has been paid to how to have access to the student's affective reactions in learning situations and how to use the student's affective state to decide the agent's behavior. In fact, there is well established research on building systems to recognize and express emotions in the same way that humans do (Picard, 1997). The term coined to this area is Affective Computing (Picard, 1997). Here, we are interested in how to design learning environments that elicit specific kinds of positive emotional responses in students (that are supposed to be more adequate to learning), motivating them to learn. In order to accomplish this role, we propose an animated pedagogical agent, called Pat (Pedagogical and Affective Tutor). We believe that the agent can induce positive emotions into the student through the presentation of emotive lifelike behavior and encouragement messages, as an empathic teacher does. The choice of an effective tactic relies on the knowledge about student's affectivity and his motivational orientation.

This paper is organized as follows. In the next section we present some related works. In section 3, we present the process of inference of the student's emotions. In section 4 we present the technologies used in Pat's implementation. Section 5 presents a scenario that illustrates the selection of the affective tactics and presentation of the corresponding animated behavior. Finally, in section 6, we present the results of the partial validation and some ideas for future work.

2. Related Works

Other works had pointed out the benefits of integrating emotions in animated pedagogical agents (Elliott et al., 1999; Lester et al., 1999; Paiva et al., 1999)[9] [14] [20]. According to Elliot (Elliott et al., 1999)[9], an emotive pedagogical agent, which shows that it cares about the student's progress, can encourage the student to give more attention to his own progress. Besides, the use of emotions makes it possible to transmit more enthusiasm to the subject to be learned and, thus to the learning. They make learning become more entertaining and motivate the student (Lester et al., 1999).

Although these systems have already integrated expression of emotions into animated pedagogical agents (Elliott et al., 1999; Lester et al., 1999; Paiva et al., 1999), their goal was mainly to make these agents more believable (to generate the illusion of life and then allow the suspension of disbelief (Bates, 1994)) and entertain the learner with the capacity of expressing emotions. Although some works (Lester et al., 1999; Paiva et al., 1999) use the agent's emotional behavior to encourage and motivate the student, this is not made by considering student's current emotions. It is important that the agent should take into account his affective state, to know the more appropriate time to encourage, motivate and praise the student and mainly how to do it. In our system, we intend to use agent's emotional attitudes and speeches as affective tactics that are chosen by considering the student's current emotions. Yet, these affective tactics have

the goal of inducing positive emotions into the student that, remembering Coles (Coles, 1998) and Izard (Izard, 1994), propitiate a more effective learning.

Other works are especially interested in inferring student's emotions (Conati, 2002; Elliott et al., 1999; Martinho, Machado, & Paiva, 2000) in order to adapt the systems to the student's affectivity. Conati (2002) propose a probabilistic model for student's emotions in educational computer games that considers 6 emotions (joy, distress, pride, shame, admiration and reproach), also based on OCC model (Ortony, Clore, & Collins, 1988). To determine student's possible goals, a questionnaire was filled by the students and they were observed playing the game. The goals are inferred by student's personality and by how the students play the game (for example, students that have the goal have_fun are more likely to move quickly). Our proposal differs from this work because we propose a methodology for inferring student's emotions (which are also determined by their goals according to OCC model) in an educational environment that is domain-independent. So, differently, the events that can happen and student's goals are not so well defined than in an educational game, and, in this way, we have to work with more incomplete information about the student.

3. The Inference of Student's Emotions

Pat has a sensor component (software) responsible for recognize student's emotions and an affective model that stores this information. The emotions are inferred by student's observable behavior, i. e., the student's actions in the system's interface. Some examples of observable behavior are: student's success or fail in the execution of an exercise, student asked for help, student did not accomplish the task. We chose this method because it seems the most natural way for the student to interact with the educational system. People can feel uncomfortable with other mechanisms as video-cameras and it can interfere in the recognition (Picard, 1997). But Pat's architecture foresees the insertion of other sensors in order to accurate the inference of emotions (see section 3) and the determination of their intensity. The student's emotion recognition by his observable behavior has been adopted by other researchers, as show the works of Martinho (Martinho et al., 2000) e Conati (2002) .

Pat is able to recognize the **joy** and **distress**, **satisfaction** and **disappointment, gratitude** and **anger**, and **shame** emotions. We model these emotions according to the OCC model (Ortony et al., 1988), which is a psychological model based on the cognitive approach of emotion. The OCC model provides information about the cognitive evaluation (called *appraisal*) that a person takes and which elicits each one of the 22 emotions cited in the book. By this way, if we know students' appraisal, we can determine their emotions. This approach is also used by (Conati, 2002; Martinho et al., 2000) for inference of emotions.

According to OCC model (Ortony et al., 1988), **joy** (respectively **distress)** emotion arises when the student is pleased (unpleased) because a desirable (undesirable) event[1] happened (did not happen). For example, the student is displeased because he did not obtain a good grade in the course. The important point about **joy** and **distress** emotions is that they result from focusing only on the desirability or

[1] In this article, the term event refers to the definition pointed out by [16]: "events are the way people perceive things that happen".

undesirability of the event. A person can also focus on other aspects of the events as well, for example that it was anticipated, or that some person was responsible for bringing it about. When this happens, different forms of emotions arise. This is the case of **satisfaction** and **disappointment** emotions. When the students focus on expected and suspected events and in the confirmation, or not, that these events will happen or happened; satisfaction and disappointment emotions can arise. For example, if the student expects to have provided a correct response to an exercise and it did not happen, he experiences disappointment emotion. The student can also focus on the agent that causes the undesirable/desirable event for him and, in this case, he will experience **gratitude** and **anger** emotion[2]. The recognition of these two emotions helps Pat to estimate how helpful it is being for the student. Yet, the student can feel **shame** when the agent that caused the undesirable event is himself.

The OCC model states that emotions are always **valenced reactions**. Joy and distress emotions are opposite valenced reactions for the evaluation of events, satisfaction and disappointment for the prospect of events, as well as gratitude and anger for the actions of another agent.

To determine student's emotions using the OCC model, we need to know his **goals**, since emotions as joy/distress, satisfaction/disappointment, gratitude/anger are elicited by the evaluation of the desirability of an event according to user's goals. We based on Ames's work (Ames, 1990) about student's motivational orientation to determine the student's high-level goal. According to Ames, students can have *mastery* or *performance* goals, which are the reasons for students engaging in learning and choosing to engage in academic tasks. Students who have a *learning/mastery goal* are oriented towards developing new skills and abilities, trying to understand their work, improving their level of competence, and learning new things (their low-level goals). When students have *performance goals* they believe that performance is important and they want to demonstrate that they have abilities. They feel successful when they please the teacher or do better than other students, rather than when they understand something new. To determine the student's goals we have used the MSLQ questionnaire (Pintrich, 1991), which was developed by a group of researchers in psychology and education of National Center for Research to Improve Postsecondary Teaching and Learning and the School of Education at University of Michigan. Pat presents this questionnaire to the student in the first time he access the educational environment.

The next step was to determine the **events** that can happen in the educational environment in order to know their desirability. In our educational environment the events can be either a student's action or an agent's action. For example, (1) "student provided and (2) did not provide a correct answer for an exercise" are examples of actions of the student; and (3) the agent did not provide a suitable help to the student is an example of an agent's action.

Knowing the event that happened and based on the information about student's motivational orientation (that shows us the student's goals: performance or learning)

[2] As in this version of Pat we are mainly interested in the affective aspects of the interaction between the student and the artificial tutor, Pat is just able to infer gratitude and anger emotions when the students feels these emotions towards the agent (Pat). As Pat is being inserted in a collaborative environment of distance learning (as mentioned in conclusion section), we aim at working with the affective aspects of the collaboration between the students in a future work.

and based on what we know about students that have these goals (Ames, 1990; Meece & McColskey, 2001), we determine the student's emotions. For example, for a *performance goal orientated* student, the event "*did not accomplish the task correctly or did not finish it*" is undesirable and elicits **distress** and **disappointment** emotions, since the expected event "*accomplish correctly a task*", which was necessary to achieve the goals "*to obtain good grade*s" and "*please the teacher and parents*" not happened. These events are even more undesirable if the student made greater effort and so elicits these emotions with higher intensity. If the *performance oriented student "accomplished the task correctly"*, it is important to know if he made effort. Students with performance orientation become more satisfied by good results obtained in tasks in which they made less effort because they think it implies high ability. Due to space restriction in this paper we cite just this example of the inference of emotions of a specific situation (an event that happened for a student with a specific goal). Actually, we infer the emotions of 22 different situations (events).

In order to measure the intensity of the emotions, we consider the variables pointed out by the OCC model. For example, the intensity of the joy/distress emotions depends mainly on the degree to which the event is desirable (its *desirability*) or not. The degree of *desirability* of an event can be measured though the information that we have about performance and mastery students. For example, we know that mastery oriented students desire more strongly to obtain a high grade. But, as we inferred the student's emotions from his observable behavior, it is very difficult for us to determine with great precision the intensity of the emotions. In this way, in this version, the emotions have just two degree of intensity: medium and high. We hope that when we will use other physiological sensors for recognizing the student's emotions (as skin conductivity and heartbeat) we will able to infer more accurately the intensity of the emotions.

This information about student's motivational orientation is also used for selecting an adequate affective tactic. For example, students that are performance oriented feel that they are not able to accomplish the task when they fail. And they usually do not make greater effort when they have difficulties, because they think it means lack of ability (Meece & McColskey, 2001). In this case, the agent presents a message for increasing students' view about their self-ability[3] (Ames, 1990; Bandura, 1994) and says to the students that they are able to carry out the task with a little more effort.

So, every time that an educational event arises (for example, the student gave up a task, or the student accomplished with success a task), the agent infers the current student's emotion and chooses an affective tactic to be applied. The definition of the affective tactics was based on studies about affectivity and learning (Coles, 1998; Meece & McColskey, 2001).

Since Pat aims at promoting a positive mood in the student, it acts in order to cancel the student's negative emotions. So, we consider that Pat's interventions always annul the student's negative emotions.

[3] Self-ability is used in this paper as synonym of self-efficacy. According to Bandura (1994), self-efficacy is concerned not with the skills one has but with judgments of what one can do with whatever skills he has.

The knowledge necessary for inferring student's emotions and for choosing the tactic is inserted in the agent in the form of BDI beliefs (Rao & Georgeff, 1995). See Section "4. Implementation Aspects" for more details.

4. Implementation Aspects

Pat's architecture is composed by two main modules: the **mind** and **body modules**. The **agent's body** is responsible for observing the student's actions (that will be used for inferring student's emotions), performing the communication with other agents, and showing the behavior and messages that compose the affective tactic selected by the mind. The **agent's mind** is responsible for recognizing the student's affective states and stores this information in the affective model, and choosing the adequate affective pedagogical tactic according to his affective state.

The Pat's mind was implemented using a BDI approach. The BDI (Rao & Georgeff, 1995) approach is based on describing the internal processing of an agent through mental attitudes - belief, desire and intention, which represents the informational, motivational and deliberative states of the agent. More specifically, we use the X-BDI (eXecutable BDI) - a BDI agent's model proposed by Móra (Móra, Lopes, Viccari, & Coelho, 1998). The model can also be used as a tool for specification of BDI agents, as an environment for implementation and execution of agents. In our work, the X-BDI was used as tool for implementation of the agent's kernel cognitive (agent's mind) because it turns easier the developer's work since it allows to specify the behavior of the agent in a high level of abstraction. The BDI implementation of the inference of the student's emotions is not the scope of this paper. Further information about this subject can be found in (Jaques & Viccari, 2007).

The body's module was implemented in Java language, more specifically, using the Java servlet and JSP technologies, which are Java technologies for developing web server pages. The communication (to send the affective tactics) between the X-BDI (developed in Prolog) and the Pat's body (developed in JSP) is made by sockets.

The lifelike character was developed in Microsoft Agent (http://www.microsoft.com/msagent/). The Microsoft Agent has already some characters to be used like Merlin and others. For the design of the character we made interviews with 10 pedagogues and psychologists in order to define its appearance and appropriate behaviors. After this study, we opted for designing the desired character, since we did not find a character that matches the characteristics specified in the interviews. The following characteristics of Pat were defined based on this study: the animated character is a full-length woman in proportion to the monitor. She has brown eyes and not too long hair, wears jeans and a colorful blouse, approximately 30 years old, because the objective is to represent a young, extrovert and informal character. In Figure 1 we can see Pat's appearance.

For the agent's speeches we use the Microsoft Speech API as voice synthesizer. Although the Microsoft technologies used in the character's implementation depends on the operational system, we opted for this software, because it offers a package for developing animated agents easy to implement and with good aspects of interface. But the system supports the character implementation in other implementation languages. For characters that work in a similar way with the Microsoft Agent, it is only necessary

to replace the JavaScript code on the relative field of the database by the code of the language used. For characters in 3D environments (like Steve (Rickel & Johnson, 1998)), it is necessary to create a component of communication between Pat's Action Module and the environment responsible for generating the movements of the character.

5. A Scenario

In order to better understand how the process of selection of an affective tactic and the behaviors that compose it are selected; let us see an illustrative scenario.

As we said previously, the student can have performance or mastery goals. Pat uses this information and the student's emotion to decide which affective tactics to apply.

Let us imagine that a female student who has **performance** goal feels **disappointed** because she **did not accomplish the task correctly.** She feels that she is not able to accomplish the task when she fails. And she usually does not do greater effort when she has difficulties, because she thinks that it means lack of ability (Meece & McColskey, 2001). In this situation the agent presents a message for increasing the student's beliefs about her self-ability and says to the student that she is able to carry out the task with a little more effort. The idea is to show to the student who has performance goal that when she did not achieve success in a task, it does not mean lack of ability, but that she can achieve better results with more effort.

For this situation, the Pat's Mind selects the following tactics. Each tactic is composed of a verbal behavior (VB) or a physical behavior (PB).

1) Increase-student-self-ability (VB: Increase-student-self-ability; PB: Encouragement);
2) Increase-student-effort (VB: Increase-student-effort; PB: Speak)
3) Offer-help (VB: Offers-help, PB: Speak).

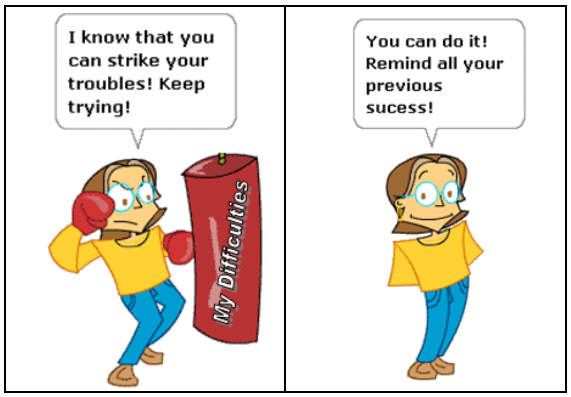

Figure 1. Examples of Animations for "Increase-student-self-ability" tactic

For example, the first tactic is increase-student-self-ability, which means to promote in the student more positive beliefs about his self-ability. For this tactic, the agent shows a verbal (VB) and a physical behavior (PB). In the example above, for the increase student-self-ability tactic, the agent chooses a VB of type "student-self-ability" and a

PB of type "Encouragement". For each type of behavior, there is more than one possible action (animation) in order for the agent to be believable.

Figure 1 shows two different examples of behaviors that can be chosen for the tactic "increase-student-self-ability".

6. Partial Validation and Future Works

As we explained in section "Implementation Aspects", for the conception of the character we made interviews with ten pedagogues and psychologists in order to define its appearance and appropriate behaviors.

For evaluating the animated pedagogical agent and also its tactics, we made a qualitative evaluation with other eight psychologists and pedagogues. For this partial study, we presented different tactics and corresponding behaviors chosen randomly to some educational situations. In this work scope, an educational situation is an emotional reaction (an emotion) of the student that has a determined motivational orientation (extrinsic or intrinsic) for a determined event. In section "A Scenario", it was presented an example of an educational situation. The validation was made in the following way. Initially, we made a brief presentation of Pat, its role and how it works with the student. After, we explained more precisely how the evaluation would be made and what we expected from the evaluators. We presented two questionnaires. The first one had the goal of being more qualitative: for each educational situation the evaluators described freely if they thought that the affective tactics and the corresponding behaviors are appropriate and why. In order to capture rich comments and critics (and also to avoid non-recorded opinions), evaluators were invited to describe their comments *in loco*, immediately after observe a determined educational situation. After the presentation and evaluation of each educational situation, they filled the second (more quantitative) questionnaire relative to the appearance of the character and its behavior. The idea (in making an evaluation with teachers, pedagogues and psychologist, instead of students) is to make use of the pedagogical experience of these professionals to verify if the affective tactics of Pat are pedagogically adequate (if they accomplish their role: encourage, motivate the student and promote in him positive emotions), and if the appearance of the character is adequate. For the evaluation above we implemented a software program that communicates with Pat's body module and asks it to present some affective tactics. This interface simulates the information that Pat receives from the educational environment.

Although the evaluators pointed out that the partial validation was a bit impaired because it was made out of its context (the evaluators could not observe Pat acting in the educational environment), in the first questionnaire, they commented that they thought the affective tactics adequate and that the agent accomplishes its role of motivating and inducing positive emotions into the student. Besides, the evaluators pointed out some considerations (for example, the voice synthesizer is not adequate to express emotions) that will be improved in future implementation of the agent (an implementation using technologies independent of operational system is also being developed).

Table 1 shows the questions presented in the second questionnaire and the percentage of the evaluator's satisfaction. For each question, they should answer if they are very unsatisfied (VU), unsatisfied (U), regular (R), satisfied (S) or very satisfied

(VS). A simple examination of the satisfaction interview in Table 1 results seems successful (generally, more than 70% of our evaluators are satisfied or very satisfied for each question). Items 1 and 2 of the table shows that they are very satisfied with the appearance of the character (more than 80% are S or VS with Pat's appearance). In relation to the attitudes (that compose its tactics) of the character presented, some evaluators were not very satisfied (generally, 25% marked that they thought the determined item Regular). They were invited to explain the cause of the evaluation when they are not satisfied with some item. Generally, the observations were the same presented in the first questionnaire: they didn't like the synthesized voice, there were some attitudes that they thought not very much adequate, and others. These suggestions are being taking into account in the new version of Pat that we are implementing.

Table 1. The percentage of evaluator's satisfaction in the second questionnaire

Character Characteristics	VU %	U %	R %	S %	VS %
1. Character Appearance					
I. Realist	-	-	13	50	37
II. Clothes	-	-	13	25	62
III. Colors	-	-	12	26	62
2. Gender					
I. Female	-	-	-	25	-
II. Male	-	-	-	-	-
III. It doesn't mind	-	-	-	-	75
3. Facial Expression and Communication					
I. Expression and Communication (in the sense of react to student's actions)	-	-	50	37	13
II. Expression of emotions	-	-	37	63	
III. Adequacy of the emotions	-	-	37	50	13
IV. Posture in the moment of interaction with the user	-	-	12	75	13
V. Changes of expressions and attitudes	-	-	25	62	13
4. Behavior of the Character					
I. Time of permanence	-	-	25	50	25
II. Dynamism: Motions and gesture	-	-	25	50	25
III. Form of interaction with user	-	-	25	62	13
IV. Mode of interference of the character (Tactics)	-	-	25	50	25

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We intend to accomplish another evaluation, with students, with Pat inserted in Eletrotutor III (Silveira & Viccari, 2002). The subject matter covered by the system is about Physics - Electricity (Ohm's Law and its applications). In this evaluation, we aim at observing a group of students using the educational system with the Pat's character and another group using the system without it. Although pedagogues and psychologists have pointed out the important role of the motivation and the affectivity in learning, we believe that this more complete evaluation can show us that the Media Equation (Reeves & Nass, 1996) also applies for this situation. It means that computers represented by lifelike characters can encourage, motivate and promote into the student positive emotions that are more adequate for learning.

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