Affective Behavior in Intelligent Tutoring Systems for Virtual Laboratories

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Abstract. One of the most important highlights of personal tutoring is that of recognizing the student’s affective state and reacting accordingly by expressing the pedagogical movements in an affectively suitable way. In this paper, we propose a model for an affective tutor. The intelligent tutor integrates an affective student model based on the OCC cognitive model of emotion, with a cognitive student model, within a virtual laboratory for teaching robotics. The main contribution of this work is in the affective behavior model, which integrates the information from the student cognitive and affective state, and the tutorial situation, to decide the best pedagogical action. We use Bayesian networks and we propose the use of a decision network with a utility measure on learning. By using the decision network, the tutor will select the best pedagogical and affective response given the current state of the student. We present some initial examples of possible affective and pedagogical responses under different situations.

Introduction

We have developed a virtual laboratory for mobile robotics [1]. Since the main goal of the virtual lab is to serve as learning tool for students, we have incorporated an Intelligent Tutoring System (ITS) into its architecture. In most developments of ITS, the tutor-student interaction has been unnatural, i.e. students interact with system by means of buttons and menus. However, in the last few years, research on human-computer interaction has tried to mimic human interaction. Most recently, researchers in computer science have turned towards an aspect which was originally believed to be unrelated to computer systems performance: emotions [2]. Scientific studies have demonstrated the influence of emotions in human communication [3]; and, a hypothesis is that it can also happen in the human-machine interaction [2]. In an ITS, this hypothesis becomes stronger, since emotions have been identified as important players in motivation, and motivation is very important for learning [4]. When a tutor recognizes the affective state of the student and responds accordingly, it may be able to motivate students and improve the learning process. There are several authors who propose to use the affective state of the student to give him a more suitable response that fits with his affective and cognitive state [5, 6, 7, 8]. However, the affective state has not yet been used to decide the pedagogical response. This is because there are still many questions about emotions without response, such as which affective states are relevant for learning.

In this paper, we propose an affective behavior model for a tutor, which combines the affective and cognitive state of the student and the tutorial situation to establish the affective and pedagogical actions. The affective behavior model integrates an affective
student model based on the OCC cognitive model of emotion, represented as a Bayesian network [9]. We are using Bayesian networks because they provide us with an effective way to manage the uncertainty involved in student modeling. The main contribution of this work is the affective behavior model; to implement it, we propose the use of a decision network. By means of the decision network, the tutor will select the best pedagogical response given the current state of the student. We present some initial examples of affective and pedagogical responses under different situations.

Section 1 describes the architecture of an affective intelligent tutoring system. Section 2 describes the affective student model. In section 3, we describe the affective behavior model. The summary of our proposal and future directions are presented in section 4.

1. Affective Intelligent Tutoring System

An intelligent tutoring system (ITS) is a computer-based educational system that provides individualized instruction similar to that of a human tutor [10]. An ITS is based on knowledge about the student (student model), on knowledge about teaching (tutor module) and on knowledge about specific domains (expert module). The basic architecture of ITS also has the interface module, which decides how should the material be presented to the student in the most effective way. An ITS decides how and what to teach, based on the student characteristics in a similar way as a human tutor. However, it has been demonstrated that an experienced human tutor manages the emotional state of the student in order to motivate him and to improve his learning process; therefore, the representation of the emotional state of the student is also needed in the ITS architecture with the purpose of provide students with more suitable instruction. A tutor who has information about the student’s affective state might provide better feedback.

In order for the tutor to obtain the capacity to recognize the student’s affective state and respond to it, the student model structure needs to be augmented to include knowledge about the affective state. Also, an affective module needs to be incorporated with the ability of reasoning about the affective state in order to provide an adequate response from a pedagogical and affective point of view. The affective module has various functions: 1) it generates and updates the affective student model, 2) it provides elements to determine the next pedagogical action to the pedagogical model, and 3) it provides the interface module elements for a physical realization of the response. In this sense, a model of affective behavior for the tutor is required. This model has to establish parameters that enable a mapping from the affective and cognitive student state to pedagogical responses. We propose an affective behavior model which is being integrated to an ITS coupled to a virtual laboratory for mobile robotics. In figure 1, we present the architecture of this affective ITS; for a more detailed description of this architecture see [1].

![Figure 1. Architecture of the ITS with the affective components (shaded).](image-url)
In order to integrate affective behavior into the ITS, we added several modules, shown shaded in figure 1. In the affective analysis module, we obtain the indicators used to infer the affective state and to update the affective student model. With this last structure, the affective behavior model will determine the affective action to be delivered by the tutor.

2. Affective Student Model

The student model must contain knowledge about the affective state of the student, in addition to knowledge about its cognitive state, with the aim of to give him an affectively adequate response at the pedagogically appropriate time. Several ways to evaluate the emotional state have been proposed: some are based on the detection of physical and biological signs [11]; others are based on the use of personality and emotion models [5]; and others are based in student interaction [6]. In this work, we use the OCC cognitive model of emotion [12] which establishes the affective state as a cognitive appraisal between goals and situation. The OCC model is one of the most known emotional models; several authors use it to establish the emotional state or to synthesize emotions [5, 13, 14]. In addition, we are using the five-factor model [15] for personality traits; the personality is very important because it determines the goals a person has, and also it determines if a person is inclined to have certain emotions instead of others emotions. Currently, the five-factor model is the most popular approach among psychologists for studying personality traits [16].

To determine the student affective state we use the following factors: 1) student personality traits, 2) student knowledge state, 3) mood, 4) goals and 5) tutorial situation. We represent the affective student model by a Causal Probabilistic Network (CPN) as shown in figure 2. The dependency relations have been established based on the literature and intuition. This way to determine the affective state is similar to the one proposed in [5].

The OCC model establishes emotional state as a cognitive appraisal between goals and situation. We represent this with the nodes goals and tutorial situation, propagating evidence to the node affective state. We think that mood influences the emotional state too; therefore we have the node mood also influencing the node affective state. Although emotional state and mood are sometimes used interchangeably, we distinguish them: mood represents the longer term emotional state, while affective state represents the instantaneous emotional state, and as is stated in [17]. Mood has an arousal level higher than emotion, i.e. mood changes slower than emotion; and, we think that both, emotion and mood, affect each other.

Accordingly to the OCC model, the goals are fundamental to determine the affective state. In order to establish student goals, we have two options: to ask the student, or to infer them. We think that asking the student is not a good option because people, in general, tend to be kind and to give kinder responses, even if the counterpart is a computer [18]. Hence, we infer them by means of personality traits and student cognitive state. We based personality traits on the five-factor model [15], which considers five dimensions for personality: openness, conscientiousness, extraversion, agreeableness, and neuroticism. At this moment, we use only two of them.
(conscientiousness, and neuroticism) to establish goals, because in literature is reported a relation with this two dimensions with learning [19]; however, we think that all five dimensions influence the affective state. The goals for our domain are: 1) to learn the topics included in the experiment, 2) to perform the experiment successfully, and 3) to do the experiment as fast as possible. Based on the OCC model we consider four possible emotional states: joy, distress, pride, shame. These states are a subset of emotional states of the OCC model.

In our implementation, we obtain the student personality traits by means a personality test [20]. We applied this test to a group of 58 students with the aim to get a priori probabilities; for a detailed description of this previous study see [21]. The knowledge student state and the tutorial situation are obtained from the student interaction with the ITS; we have a relational probabilistic student model; for details this model see [22].

3. Affective Behavior Model

Once the affective student model has been obtained, the tutor has to respond accordingly; consequently, the tutor needs a model of affective behavior. The affective behavior model (ABM) establishes parameters that enable a mapping from the affective and cognitive student models to the responses of the tutor. Figure 3 shows a block diagram for the ABM.

The ABM receives information from three components: the affective student model, the cognitive student model and the tutorial situation. The ABM translates these components into affective actions for the tutor and interface modules. The affective action contains knowledge about the overall situation that will help the tutor module to determine the next response to the student, and also will advise the interface module to express the response in a suitable way.

Based on the affective action, the tutor module can decide if it is necessary to provide another exercise or to change the topic in turn. For example, if the student’s response is incorrect and his affective state is happy, the tutor can encourage the student with another exercise more suitable to the situation in order to maintain high motivation. In figure 4, we present an abstract representation of the ABM by means of a decision network. The affective action considers utilities in learning of the student. We are currently developing a more detailed representation for the ABM.
3.1 Affective Action

The affective actions are the product of the ABM. The affective action is composed of the pedagogical sub-action (knowledge to the tutor module) and interface sub-action (knowledge to the interface module). These sub-actions will be used in a way that will be determined by the specific ITS, and particularly by its tutor and interface modules; that is, the domain of the ITS and the technology used in the user interface. For the time being, we have identified three classes of affective actions: neutral, moderate and strong.

Fundamentally, a neutral and a moderate action applies when the level of motivation is good (the motivation increases or remains at same level), and it determines that the tutor’s next pedagogical action can employ the same pedagogical strategy used at that moment; i.e., the instruction is working. A strong action applies when the student’s motivation decreases and it is necessary to execute some action to attract his attention; for example, to change the rhythm of instruction to faster or slower depending on the cognitive student model. At this time, the pedagogical sub-action is determined with base in the tutoring experience of the authors, and they represent the basic movements of a novice human tutor.

The pedagogical sub-action tells the tutor module if it must continue on the same topic or move forward or backward, but the pedagogical movement (explanation, exercise, example, etc.) must be established by the tutor module. The interface sub-action specifies one of the following three levels of affectivity: 1) when the motivation increases or remains on the same level because the student is doing well; 2) when the motivation slightly decreases due to an error; and 3) when the motivation dramatically decreases because the student has had various errors. This will tell the interface module how the physical realization should be. The technology used in the user interface will determine what specific actions are delivered to the student and in which way.

In order to show some actions of the ABM, we present in table 1 some examples of its application to different situations. The table shows the affective action and sub-action, as well as the pedagogical response, for different cognitive states and tutorial situation. The ABM is being implemented in Elvira System [23].

<table>
<thead>
<tr>
<th>Cognitive State</th>
<th>Tutorial Situation</th>
<th>Affective State</th>
<th>Affective Action</th>
<th>Affective Sub-action</th>
<th>Example of Pedagogical Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive Joy</td>
<td>Neutral</td>
<td>Neutral</td>
<td>Same topic</td>
<td>Present another exercise with higher difficulty level</td>
<td></td>
</tr>
<tr>
<td>Student knows the topic in turn</td>
<td>Negative Distress</td>
<td>Strong</td>
<td>Same topic</td>
<td>Present another exercise with lower difficulty level</td>
<td></td>
</tr>
<tr>
<td>Positive Joy</td>
<td>Neutral</td>
<td>Neutral</td>
<td>Same topic</td>
<td>Present another exercise with higher difficulty level</td>
<td></td>
</tr>
<tr>
<td>Student does not know the topic in turn</td>
<td>Negative Distress</td>
<td>Strong</td>
<td>Same topic</td>
<td>Explain the topic again, in another way</td>
<td></td>
</tr>
</tbody>
</table>

4. Conclusions and Future Work

In this paper, we proposed an affective behavior model for an intelligent tutoring system coupled to a virtual laboratory. Our main contribution is establishing a pedagogical response given an affective state. We have presented an affective student model based on the OCC model, and an initial affective behavior model that combines the cognitive and affective states to establish pedagogical and affective responses.

Currently, we are constructing the affective student model, using questionnaires to obtain the prior probabilities; and integrating it to the cognitive student model used in the virtual laboratory [1]. We are also preparing some tests, such as Wizard of Oz experiments, that may provide insight for the formalization of the affective model. To validate the model
we plan a summative evaluation. In the first phase of the evaluation, we will have a group of 20 students interacting with the ITS without affective behavior, and in a future phase, we will have another group of 20 students working with the ITS with affective behavior.

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