An agent model of student's affect for adapting schooling strategies

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Abstract. In this paper, we present a student's affective model that considers a temporal and multi-dimensional view of the student. It considers three dimensions (i.e., individual, environmental, and social dimension), which contain static and dynamic features. Based on this model, we define a MAS, that includes emotional agents able to simulate student's and their affective state. This system allows to simulate the effects of changes in lessons over the affective state of students.

Keywords: cognitive, emotion, affect, agents, modeling

1 Introduction

Affective characteristics (such as emotions) play an essential role in education. They influence students' and teachers' interest, engagement, and achievement, and, in a more general level, the well-being of students. The main question is, how can we adapt education? More specifically, how can teachers use student's affective information in order to improve teacher's schedule and schooling strategies in the teaching sessions, and hence, improving students-related learning factors such as: satisfaction, percentage of comprehension, knowledge speed acquisition, and motivation?. Practical considerations on how to modify students' and teachers' emotions can be extracted from the analysis of the results obtained from classrooms observations or from theoretical considerations. Therefore, in this paper, we propose a model that helps teachers to assess what can be done to prevent or reduce negative emotions (i.e., anger, hopelessness, or boredom) in students, and to promote their positive emotions (i.e., hope, pride, and enjoyment) in teaching and learning.

Emotions should be addressed from a multi-dimensional perspective by "addressing the variation of emotions between individuals, activities, and subject domains, as well as classrooms" [1]. For instance, by analyzing whether the variation of emotional experiences can be explained by differences between academic activities, like attending to a class vs. taking exams, or between different academic subjects, and to what extent. It is also important to determine which of these variables play a critical role on the variation of classrooms' emotional climate. These issues are of fundamental importance for adequately designing educational interventions [1].

In this paper, we propose a computational approach that offers a practical way of evaluating the impact of different schooling strategies on the students affective state. The computational approach is based on an agent model that

integrates relevant factors that influence the affective state of a student. The aim of the approach proposed in the paper is to facilitate the estimation of the impact of schooling strategies with the minimum intervention of students.

The paper is organized as follows. Section 2 presents proposals that analyze the influence of emotions in learning process. Section 3 describes the agent model that integrates individual, environmental, and social factors that influence in the student's affective state, and therefore, in his/her learning process. Section 4.1 defines the stages of the process for gathering information in real learning environments and for including it in a computational approach. The computational approach is based on a multi-agent system that facilitates the simulation of the effects of schooling strategies over the students affective state and learning process.

2 Related Work

The influence of affective characteristics on the cognitive processes and behavior of an individual has been systematically demonstrated across several disciplines. Emotions, personality or mood are among the affect-related cognitive concepts that have been more widely addressed [2, 3]. Emotions are known to be the result of an appraisal of certain stimuli that can be events, objects, or other individuals [4–6]. Personality can be defined as the "dynamic and organized set of characteristics possessed by a person that uniquely influences his or her cognitions, motivations, and behaviors in various situations" [3]. Mood, as emotions, characterizes the affective state of an individual but mood's intensity is lower than emotions' intensity and it represents long-lasting affective states, while emotions have a brief duration [2]. In particular, these affect-related concepts and their influence on cognition and behavior, have been widely investigated for teaching and learning. One of the domains that has most widely studied affect on teaching and learning is e-Learning. For example, in [7] authors propose a model for predicting an agent emotional reaction in a distant environment of learning by using personal characteristics and non-personal data. Also, S. Chaffar *et al.* created a methodology that also starts from the learner's individual information (personality, and motivation) and environmental factors (tutor's intervention type) for predicting the learner's emotional reactions by using a Naïve Bayes classifier [8]. Also, a model for selecting a suitable virtual classmate on the base of student's personality and emotions is proposed in [9].

The Control-Value Theory of Achievement Emotions of R. Pekrun *et al.* [1], is maybe the approach that most closely resembles ours. This theory proposes an appraisal model for ongoing achievement activities, their past and future outcomes where environmental, social and individual factors are appraised. The theory also focuses on the influence of emotions on academic engagement and performance. We focus instead on finding the linkage between the combination of several dimensions (individual, environmental, and social), and a variation on the students emotional state Also, our approach looks for schooling methodologies that better fit student's requirements and current situation, by switching

different schooling methodologies and techniques, on the base of an "improvement" of the students' emotional state. It offers a practical way of evaluating the impact of different schooling strategies on the students affective state, and hence in their well being in relation to those strategies. This way the probability of a better learning process and a better students performance grows, as proved by several previous studies and results. By focusing on particular and comprehensive aspects and on a particular design, our approach makes possible the implementation of a computational system able to predict the impact of schooling strategies with the minimum intervention of students.

3 Student's Affective Model

We propose a student's model that considers a set of circumstances that influences in the affective-state of individuals and, therefore, in the effects over a set of learning factors that is interesting to evaluate. The set of circumstances is composed of three dimensions: *individual*, *environmental*, and *social*. In each dimension, we consider relevant features that maintain their value during a long period of time (i.e., course, school year or semester), and features that are dynamic and change their value with a higher frequency (i.e., during a lesson).

The *individual dimension* has two static features: concerns and personality. Concerns represent the individual *achievement goals* of the student in the long term (i.e., learn as much as they can about a subject, personal satisfaction, doing the minimum effort to pass the course, or doing well on exams to obtain a high mark). The relationship between personality and learning is largely documented [10]. We considered the Big Five personality traits [11], in order to characterize the student personality. Combinations of Big Five traits have also been found to predict various educational outcomes. The individual dimension has one dynamic feature: expectations. People tend to behave in such a way that their behavior optimally matches their expectations. The knowledge of student expectations can be also useful for adapting the design of teaching programs or the teaching strategies and methodologies [12]. For instance, if teachers know what their students expect, they may be able to adapt their behavior to their students' underlying expectations, which should have a positive impact on their levels of satisfaction [13].

In *environmental dimension*, the static set of features are those environmental circumstances around the learning context that remain constant during a course or semester. In the dynamic set of features, we consider features that change their value more frequently such as the teaching methodology used by the teacher (i.e., teacher-centered approach or student-centered approach), the position of the lesson in the school year schedule, scheduled events (i.e., exams, holidays, deliverables, etc.), the task performed during the lesson (i.e, the provision of realistic, challenging, or appropriate tasks, etc.).

The *social dimension* is characterized by a set of dynamic features. The classroom climate is one of the factors to consider in the social context and can be classified in: (a) consistently positive and supportive, (b) consistently negative and nonsupportive, and (c) ambiguous. The students-teacher relationship has

an effect on student's emotions. For instance, teachers and students can create positive climates for learning alignment between a person's goals and the goals of the classroom [14]. The relation between a student and a peer group is also important and influence in students feelings and emotions such as those related to the achievement success or failure, as well as acceptance or rejection by others [15], or the alignment of peers' academic aspiration [16].

These three dimensions compose the circumstance of the student that has a direct influence over the affective-state of the student. The emotional part of the student has been represented in the model through the affective-state. According to [17], affect seems to be a best term to describe emotions over time. The model includes two ways of establishing the student's emotion: through the PAD model (Pleasure, Arousal, and Dominance), and through an emotion aggregation of emotions that are directly related to students and learning environments. The affective-state of the student influences in *factors in the learning context*. These factors are classified in the model as short-term factors (i.e., students satisfaction, percentage of comprehension, knowledge speed acquisition, and motivation) and long-term factors (i.e., academic results, and satisfaction).

4 Workflow

In this section, we describe a general workflow stages and their most important features where the student's affective model and the proposed computational model are integrated. The stages are divided into two main parts (see Figure 1): *real learning environment* and *simulation*.

Real learning environment includes the set of stages that are required to collect information about students' features that emerge during a lesson. In Stage 1, students fill a survey with information about their individual dimension and the teacher establishes some features of the environmental dimension. Before a lesson starts, students express their affective state using a PAD model in Stage 2, and then, the lesson starts. During Stage 3, the lesson is performed. In Stage 4 (which takes place at the end of the lesson), students provide information about their affective state through a form that includes a set of emotions related to learning. Then, before the next lesson, students can update information about their social dimension or their expectations, which corresponds to Stage 5. The teacher can modify environmental dimension in order to see how changes in the environment modify students' affective state and expectations or the social dimension during the period of time of a lesson. The information collected in each lesson of several subjects during a course is stored and used as input for the *simulation*. This process for gathering information is repeated in each lesson[1].

Simulation starts by processing all the information collected from the real world. Using learning and reasoning techniques (i.e., machine-learning and case-based reasoning) individuals from the real learning environment are classified

[1] Note that, once the data is filled the first time, the students or the teacher do not necessarily require to repeat all the steps at each lesson

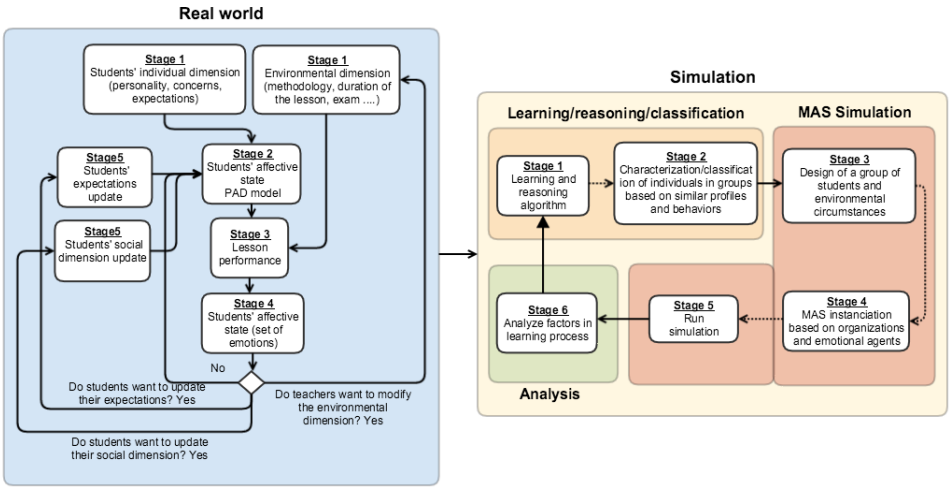

Fig. 1. Workflow process in the real-world and simulation.

into groups of students with similar profiles and behaviors. Once a set of students categories has been extracted and the teacher has decided the environmental circumstances that s/he would like to test (i.e., type of methodology, tasks, group activity, etc.), the Multi-Agent System (MAS) is instantiated and the simulation starts. The MAS is based on the proposed student's affective model described in Section 3. After the simulation, results from the simulation are analyzed and used as input for the learning and reasoning process. In the meanwhile, new data obtained from students' experience during lessons in the real learning environment can be also considered as input for the learning and reasoning process that will provide feedback to the simulation.

4.1 Multi-Agent Architecture for Educational Environments

The main component of the simulation part is the Multi-Agent System (MAS). The proposed MAS is based on THOMAS [18] and the student's affective model described in Section 3. The proposed MAS is made up of a set of virtual organizations (VO) (i.e, group of students that are enrolled in a subject) and emotional autonomous agents (i.e., students) that are, at least, in one VO (i.e, they are at least enrolled in one subject). These agents interact and are influenced by other agents, environmental conditions, their individual characteristics, and the events that occur in the VO (subject).

Formally, the proposed MAS can be defined as follows:

DEFINITION **1** *(System). The system is a tuple* (VO, A)*, where* VO *is a set of virtual organizations (i.e., subjects)* $VO = \{VO_1, \ldots, VO_n\}$ *and* A *is a finite set of emotional autonomous agents (i.e., students)* $A = a_1, ..., a_n$*, where each agent* a_j *should belong at least to one* $VO_i \in VO$*.*

A virtual organization in the proposed computational model considers information about learning goals, the profiles that appear during a lesson (i.e., students and teacher), and the actions associated to these profiles.

DEFINITION **2** *(Virtual Organization). The VO_i is defined as $(\mathcal{G}_i, SD_i, FD_i)$ where:*

- $\mathcal{G}_i = \{g_1, \dots g_n\}$ *is the set of goals associated to the virtual organization. In the educational context, the goals of an organization correspond to improving learning factors such as satisfaction, percentage of comprehension, knowledge speed acquisition, and motivation.*
- $SD_i = \{E_i, OR_i, Relations\}$ *is the structural dimension that defines roles and relations among entities. E_i refers to the set of entities (virtual organizations, agents, or both) that are inside the organization. For instance, students that are enrolled in a subject (i.e., agents that belong to a VO_i) or a seminar that is inside a subject (i.e., VO_i inside a VO_k). $OR_i \in R$ refers to the roles that can be played inside the organization (i.e., teacher, student, group leader, etc.). Relations defines the relationship among roles inside the organization. The organizational topology in this context is hierarchical where the teacher is in the first level of the hierarchy and students in the second level. More roles can be defined and other structures considered.*
- FD_i *is the functional dimension. It describes the set of actions that agents can do. For instance, in the context of a lesson, the actions that a teacher may perform are: starting a new lesson, proposing activities, or establish a methodology among others. Actions related to students can be: assist to a lesson, participate, or take an exam among others.*

Considering the student's affective model described in section 3, we formally define the Emotional Agent.

DEFINITION **3** *(Emotional Agent). The emotional agent a_j represents a student and is characterized by a tuple (I_j, En_j, S_j, Aff_j) where:*

- $I_j = \{C_j, P_j, Ex_j, r_j\}$ *represents the individual dimension that consists of: C_j represents the concerns of the agent (i.e., get good marks, learning, pass all the exams, enjoy), P_j represents the personality of the agent (i.e., Big Five personality), Ex_j represents the expectations of the agent (i.e., finish the tasks, understand the new concepts of a lesson, end the lesson without doubts), r_j the role that the agent plays (i.e., teacher, student, spokesperson, etc.),*
- En_j *represents the agent's knowledge about the environment where the agent is located (i.e., class duration, timetable, subject, breaks, learning methodology, lesson's number, tasks, exams' results, etc.),*
- S_j *represents the social dimension (i.e., classroom climate, student-peers relation, teacher-student relation),*
- Aff_j *represents the affective state in a temporal point as an aggregation of emotions related to the learning process.*

DEFINITION **4** *(Role) A role $r_\ell \in OR_i$ is defined by the tuple $(\phi_\ell, Act_{r\ell})$, where:*

- *ϕ_ℓ is the role's name. In educational context the roles would be teacher and student.*
- *Act_{r_ℓ} is the set of actions associated to the role. Each action is defined by the tuple $(In_\ell, O_\ell, P_\ell, Eff_\ell)$ (i.e., Inputs, Outputs, Preconditions, and Effects). For instance, in an educational context, the actions associated to the role teacher could be: starting a new lesson, proposing activities, or establish a methodology.*

The proposed computational model allow us to define a MAS where emotional agents (i.e., students) can interact autonomously in the context of a virtual organization (i.e., an specific subject). Each agent that plays the role *student* has a set of beliefs about itself, the environment, and the relationship with others. Agents have also a set of possible actions (i.e., participate, interact with peers, submit tasks, do an exam, etc.). These actions may imply a change in the beliefs of other agents with whom they interact. Moreover, in each virtual organization, there is an agent that plays the role *teacher*. This role has associated a set of actions that can update information about the environment (i.e., the lesson) such as create an individual activity, update methodology, or evaluate. When there is a change in the environment, agents are informed and they, based on their circumstances (i.e., their beliefs about their individual, environmental and social dimensions) can update their affective state accordingly, and, therefore update degree of achievement of the learning goals of the virtual organization. All these features of the computational approach facilitate the simulation of virtual learning environments where is possible to estimate the impact of schooling strategies over the learning process with the minimum intervention of students.

5 Conclusions

Emotions play an important role in learning environments. In this paper, we propose a model that considers a set of factors from a temporal multi-level perspective and events that influence on student's emotions. This temporal multi-level perspective considers three dimensions that include static and dynamic features: individual (i.e., concerns, personality, and expectations), environmental (i.e., features related to lesson's planning and organization), and social (i.e., classroom-climate, student-peers relation, teacher-student relation). This set of features and events that can occur during a lesson, influences on student's emotions, and therefore, in the expected learning factors such as satisfaction, knowledge acquisition, motivation, or comprehension. Based on this model for analyzing the factors that influence student's affective state, we propose a MAS architecture based on organizations that integrates emotional agents to incorporate the student's affective model and be able to simulate the effects of changes in the environment (i.e., the lesson) over the affective-state of students. We also present the workflow for the inclusion of information collected about these effects over the student's affective state in real and simulated environments. As future work, we plan to validate our proposal by applying it in a real educational environment.

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