Inferring Learner’s Emotions Adopting an Ontological Approach

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Abstract - The aim of this paper is to present a method to elicit learner’s emotions during the learning process making use of an ontology. The elicitation of emotions is based on a formal representation of emotions using an appropriate designed ontology and it is achieved by a combinational probabilistic machine learning method. The development of this ontology serves not only as a basis for the formal representation of emotions but also contributes to their efficient management in an Affective Module. The Affective Module is integrated in a Web-Based Adaptive Educational System which is named MENTOR and supports personalized distance learning. The foremost and endmost goal of MENTOR is to provide the learner with a more personalized and friendly environment for learning, according to his personality, mood and emotions.

Keywords: Affective computing in Education, Ontology, Artificial Intelligence, Personalization, Distance e-Learning.

1 Introduction

Most recently, research in computer science has begun to take emotions into account, because their influence in perception, reasoning, decision-making and learning is considered catalytic [7]. Especially in education, the appropriate emotional background constitutes an important factor and a significant requirement for the accomplishment of learning goals.

On the other hand, the Internet is the ideal environment for the promotion of the personalized learning according to the student needs. Various educational systems as the Adaptive Educational Systems (AES) and lately the Web Based Educational Systems (WBES) have been developed to this direction. These systems allow the identification of learning needs of students, support the appropriate presentation of the instructive material and the selection of the suitable learning strategies. At the same time, the system monitors the student progress, supports properly his efforts when it is necessary and evaluates him.

However, these systems in their majority develop their educational dimension, based only on cognitive parameters such as learning styles, without taking into consideration the emotional factors that are related to the mood and the personality of the student. Many Web learning designers realize that this omission deprives the education from a very important pedagogical dimension. Thus, they conceive the necessity to turn their attention in affective subjects which influence the learning.

In this paper we present an Affective Module which is integrated in a MENTOR Web-Based Adaptive Educational System for personalized learning, as well as a method for the elicitation of student’s emotions during the learning process. In this frame we also examine several affective matters in order to present a proposal for the formal representation of learner’s emotions. This formal representation is implemented via an ontology and correlates the individual learning preferences of a student with his personality and his current emotional states. The development of the ontology is based on the cognitive model of emotions, which has been proposed by Ortony, Clore and Collins (OCC) [6], and is widely known as the OCC model. This model is used in combination with a probabilistic approach, with the aim of predicting the emotional reactions of the student as they are expressed in the specific context of MENTOR’s educational environment. In this way, the learner is provided with a personal and friendly educational environment according to his personality and emotional state. As a result, the student is given the sense that he does not have to deal with a "cold" environment of education, but with a teaching room where the teacher cares about his student and the knowledge is built on suitable sentimental foundations.

2 Basic Concepts of Affecting Computing

The term Affective Computing involves the intention of Artificial Intelligence researchers to model emotions in intelligent systems. According to Picard [7] an affective system must be capable of recognizing emotions, responding properly to them and reacting “emotionally”.

2.1 Personality and Five-Factor Model

The personality determines all those characteristics that distinguish one human being from another. It has a permanent character. The most known model of personality is the Five Factor Model (FFM) [9] and results from the study of Costa and McCrae [2]. It is a descriptive model with five dimensions: Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. Due to these dimensions the
model is also called OCEAN model. The descriptive character of FFM and the particular characteristics that accompany each type of personality (traits) allow us to model the learner’s personality [5] and use this information in educational applications [1].

The FFM provides us with a reliable way in order to connect a learner’s personality with his mood and emotions that he possibly experiences during the learning process. This is very useful because we are able to initiate learner’s emotional state and select the suitable pedagogical strategy.

2.2 Emotions, Mood and the OCC model

There is not an explicit definition for the emotion. It is easy to feel, but it is hard to describe it. Nevertheless, various attempts have been made, but the cognitive theory of emotions, known as OCC model, which formulated by Ortony, Clore and Collins [6], keeps a distinctive position among them. The three authors constructed a cognitive theory of emotion that explains the origins of emotions, describing the cognitive processes that elicit them. The OCC model provides a classification scheme for 22 emotions based on a valence reaction to events, objects and agents. The events are evaluated in terms of their desirability, according to the goals of the subject. Standards are used to evaluate actions of a subject and objects are evaluated as appealing depending on the compatibility of their attributes with subject’s attitudes. According to Scherer [8], emotion is the synchronized response all or most organic systems to the evaluation of an external or internal event.

Emotion is analogous to a state of mind that is only momentary. Mood is a prolonged state of mind, resulting from a cumulative effect of emotions [8]. Mood differs from the emotion because it has lower intensity and longer duration. Based on this definition we categorize mood into two categories named, positive and negative. We consider that the student has either a positive mood when he feels emotions like joy, pride, hope, satisfaction, gratification, love, or a negative mood when feels emotions like sadness, fear, shame, frustration, anger, disappointment, anxiety. Depending on this mood, we speculate the possible emotions of the student. In this paper we adopt the OCC model, because it elicits the origin of emotions under a cognitive aspect and it is possible to be computerized. Therefore, based on this model we are able to classify and interpret student’s emotions in the learning process. The authors of the OCC model consider that it could be computationally implemented and help us to understand which are the emotions that the human beings feel and under which conditions. Furthermore, they believe that relying on this model, we could predict and explain human reactions to the events and objects. This is the main reason we use the OCC model in our study. The perspective by which we construct the following model is interdisciplinary and focuses in the intersection of Artificial Intelligence and Cognitive Psychology.

3 The Architecture of the Affective Module

In the real educational process, the teacher takes into consideration the emotional state of his student by motivating him effectively and achieving thus, the desirable learning goals. Consequently, the investment in individual differences and the emotional “potential” of the student in combination with his cognitive abilities could be a significant factor, so that the learning goals can be achieved more efficiently, from a pedagogical point of view. Many researchers have demonstrated the pedagogical value of personality and emotions and incorporated this perception into their educational systems [1], [10], [11].

MENTOR is a WBES which incorporates an Affective Module in order to recognize the learner’s emotions during his interaction with the educational environment and thereafter to provide him with an appropriate learning strategy [4]. The operation of the Affective Module is based on the FFM [9] and the OCC model [6] with the aim of providing MENTOR with the essential “emotional” information in order to determine the suitable strategy of learning. The emotional information is combining with the cognitive information which is stored in the affective learner model. In this way the selection process of the proper learning method is enhanced with the affective dimension. The architecture of MENTOR’s Affective Module is presented in figure 1.

![Figure 1: The architecture of the MENTOR’s Affective Module](image)

MENTOR has three main components: The Emotional Component (EC), the Teacher Component (TC) and the Visualization Component (VC), which are respectively responsible for a) the recognition of student’s personality (PR), mood (MR) and emotions (ER) during the learning process, b) the selection of the suitable teaching (TG) and pedagogical strategy (PG) and c) the appropriate visualization.
of the educational environment. The combined function of these components “feeds” the MENTOR with the affective dimension optimizing the effectiveness of learning process and enhancing the personalized teaching. Further analysis of the operation of the Teacher and the Visualization Component is beyond the scope of this paper which is focused on the Emotional Component.

The Emotional Component is in every moment aware of the learner’s emotions during the learning process. Several ways have been proposed about the recognition of emotions. Some of them are based on the detection of physical and biological signs [7] and others are based on AI techniques like Neural Networks [12], Fuzzy Logic [5], Transition Networks [15], or Dynamic Decision Networks (DNNs) [1]. In the following two sections, we describe the method which is used by the Emotional Component of MENTOR in order to (i) represent the emotions of the learner in a formal way, and (ii) elicit his emotions during the learning process.

4 The Ontological Representation of the Learner’s Emotions

Ontology is a formal way to represent the specific knowledge of a domain, providing an explicit and extendable framework to describe it. Lastly, except from AI, a lot of fields in Information Science such as Knowledge Engineering and Management, the Semantic Web, Bio-informatics and Education make use of ontologies [13], [14]. As a result, a wide range of applications which incorporate ontological approaches has been produced.

Ontology is a technique of describing formally and explicitly the vocabulary of a domain in terms of concepts, classes, instances, relations, axioms, constraints and inference rules. This schema can be defined in a machine–accessible way so as to be suitable for sharing among various systems, understandable between humans and machines and appropriate for meta-data and semantics encoding as well.

Taking advantage of the above benefits, we use an ontology of emotions in order to achieve a formal and proper representation of the affective learner model and to reason and infer efficiently with the affective factors which occur during the learning process. The structure of the proposed ontology is in compliance with the OCC emotions classification and has been adjusted suitably in order to attain the requiring knowledge representation for our educational system. This ontology, which is an application – domain ontology, contains the necessary affective information to model and support specifically the operations of the MENTOR.

According to the above analysis the main purpose of the proposed ontology is the formal representation of the student’s emotions which our system particularly deals with. The ontology has been built to be aware of 10 emotions which are: joy, satisfaction, pride, hope, gratification, distress, disappointment, shame, fear, reproach. The former five emotions comprise the classification of positive emotions and are related to the positive student’s emotional state. The latter five emotions comprise the classification of negative emotions and are related to the negative student’s emotional state. As it has already been referred, the construction of the ontology is based on the OCC cognitive theory of emotions. Thus, the concepts of the ontology are defined in terms of this theory. For instance, the positive and negative student’s emotional states and the emotions of joy and satisfaction are describing as follows:

\[
\text{POSITIVE-EMOTIONAL-STATE}
\]

\[
\text{SUBCLASSES}
\]

\[
\text{VALUE (JOY, SATISFACTION, PRIDE, HOPE, GRATIFICATION))}
\]

\[
\text{IS-A}
\]

\[
\text{VALUE (EMOTIONAL-EVENT))}
\]

\[
\text{DEFINITION (VALUE ("emotions or states, regarded as positive, such as joy, satisfaction, pride, hope, gratification"))}
\]

\[
\text{NEGATIVE-EMOTIONAL-STATE}
\]

\[
\text{SUBCLASSES}
\]

\[
\text{VALUE (DISTRESS, DISAPPOINTMENT, SHAME, FEAR, REPROACH))}
\]

\[
\text{IS-A}
\]

\[
\text{VALUE (EMOTIONAL-EVENT))}
\]

\[
\text{DEFINITION (VALUE ("emotions or states regarded as negative, such as distress, disappointment, shame, fear, reproach "))}
\]

\[
\text{JOY}
\]

\[
\text{IS-A}
\]

\[
\text{VALUE (POSITIVE- EMOTIONAL-STATE))}
\]

\[
\text{DEFINITION}
\]

\[
\text{VALUE ("pleased about a desirable event ")}
\]

\[
\text{SATISFACTION}
\]
Figure 2: An Excerpt from the ontology of student’s emotions.

The ontology of emotions is comprised of one main class the Student-Emotion class. The Student-Emotion class is divided into two sub-classes the Positive-Emotional-State sub-class and the Negative-Emotional-State sub-class. Every of ten selected emotions is represented as a second layer sub-class, into these sub-classes. The hierarchy of the proposed class is shown in figure 2. We use the DL-OWL (Description Logic – Ontology Web Language) as a reasoning and inference mechanism to obtain the essential production rules, as well as analyze the domain knowledge and interaction data. For instance, the emotion of fear is represented as:

\text{\textit{\textup{fear}}}_{\iota}(P, \neg G) \text{ means that the student who is performing a plan } P, \text{ feels fear the particular period of time } t_i \text{ that will not accomplish his learning goal } G.

In this way, the formal and flexible representation of an emotion can be achieved in relation to the learning goal of a student. The proposed ontology of emotions was implemented with the Protégé tool.

5 The Elicitation of the Learner’s Emotions

The necessity of recognizing the learner’s emotion during the learning process, especially in distance learning environments is crucial and has been pointed out by many researchers in the e-learning field. Towards this need many methods have been proposed with the aim of recognizing or predicting student’s emotions. Some of them are based on AI techniques like Dynamic Decision Networks (DNNs) [1], Hidden Markov Models [17], or Transition Networks [15]. Inferring student’s emotions in an on-line educational environment is a multi-parameter and highly demanding task. The inference of student’s emotions presupposes the awareness of many factors like his personality, mood, current emotional state and learning goals. All these factors must be considered during the learning process and progress of the learner, taking into account the constraints of the particular educational context.

As it has been already referred, the Emotional Component of the MENTOR’s Affective Module is responsible for the elicitation of ten learner’s emotions, which respectively are, joy, satisfaction, pride, hope, gratification, distress, disappointment, shame, fear, reproach. The method we have followed to achieve this is relied on two different perspectives. The first one is based on a probabilistic point of view. It makes use of the intrinsic traits of the learner as well as the likelihood of transiting from one emotion to another, in order to predict his next emotional state. The second is based on the OCC model which combines the appraisal of an Event with the Intentions and Desires of a subject. Thus, taking advantage of this model, MENTOR infers student’s emotions after the occurrence of an educational event which is related to the student’s learning goal. These two perspectives are incorporated into a DL-OWL inference engine in order to make predictions about the emotional state of the student.

The initialization of the above emotions is realized at the starting session of the interaction. An initial dialogue is established between the system and the learner where after a sequence of appropriate selected questions the former determines the current emotional state of the latter (figure 3). After that, the learner is provided with a NEO-PI-R questionnaire [3], which its completion aims to the identification of the type of student’s personality. The second step is performed once, at the first time that the student uses the system.

Figure 3: The initialization process of the learner’s emotional state recognition.
According to the first perspective we consider as $P_{in}(E_i)$, $i=1,2…,10$ the probability of each emotional situation at a given period of time $t_i$ which is related with the intrinsic characteristics of the student’s personality as it is identified by the entry test. We consider as $P_{tr}(s_a|s_b, E_i)$, $i=1,2…,10$ the probability of each emotional situation at a given period of time $t_i$ which is related to the transition from one emotional state $s_a$ to another emotional state $s_b$ and as $P_{tr}(s_a|s_b, E_i)$, $a\neq b$ the probability of this transition.

$$\sum_i P_{in}(E_i) = 1, i=1,2…,10 \quad (1)$$

$$\sum_i P_{tr}(s_a|s_b, E_i) = 1, i=1,2…,10 \quad (2)$$

These probabilities obtained by psychological experimental questionnaires [15] in relation to the events which occurred in the educational system. For this reason, our module is restricted to elicit ten emotions and it hypothesizes that every emotional state is independent from each other.

Comparing these probabilities by making of use the difference between them, we can select the emotional states’ probability with the smaller result. The equation which is used to calculate the associated difference between these probabilities is:

$$P_{dif} = \sum_i | P_{in}(E_i) - P_{tr}(s_a|s_b, E_i) | , i=1,2…,10 \quad (3)$$

If the $P_{dif}$ is less than a threshold $L$ which is determined by the individual personality traits of every student, we can infer with great confidence about the exact emotional state of the student. Usually this threshold cannot be greater than 0.1, that is: $P_{dif} \leq L$. In this way we have an initial estimation about the emotion of the student in a particular period of time in relation with a specific educational event.

On the other hand, according to the second perspective, we adopt a decision tree approach to extract information from the proposed “emotional” ontology and to infer about the emotions of the learner. This process comprises of three steps which respectively are the following:

1. The creation of the decision tree
2. The extraction of the rules from the decision tree
3. The triggering of the extracted rules to infer learner’s emotions

More analytically, during the first step the C4.5 algorithm [16] is applied to the ontology’s data, building in this way the decision tree from the set of information data. The set of data is the already classified emotions and represents the attributes of the sample. We choose the C4.5 algorithm because it takes advantage of the fact that each attribute of the data can be used to make a decision that splits the data into smaller subsets. Afterwards, the normalized information gain is examined with the aim of choosing the attribute with the highest normalized value from the splitting data. The data which are used to produce the decision tree are the desirability of the educational goal, the achievement of the goal, the praiseworthiness of the educational goal, the positiveness of student’s emotional state, the type of personality of the student and the probability of feeling the particular emotion. In the second step, the creation of the decision tree is followed by the conversion to rules. The generation of rules is realized by tracing each path in the decision tree, from root node to leaf node, recording the test outcomes as the antecedents and the leaf-node classification as the consequent. The produced rules are stored in the Rule’s Data Base of the Emotional Component. During the last step, the extracted rules are triggering according to the learning goals of the student with the purpose of inferring his emotions.

After the completeness of this process the Emotional Component can infer about the dominant emotion of the student. At this point we can confirm the emotion which has been already elicited with the first method. Both these methods have concluded to the same emotion, so the Emotional Component can infer with great confidence that this emotion is the prevalent for this time of period.

Let us consider the following example. An Openness student is tested in the entry session and is found to be in a positive emotional state. According to his personality the $P_i$ for every emotion is likely to be 0.5 for joy, 0.2 for satisfaction and 0.3 for pride. This emotional state is retained until the next time period when an educational event occurs. This event is the assignment of a test which is comprised from 10 questions. There are three possibilities for the student, to answer, not to answer or to avoid answering. In the first case he hopes that he will answer correctly. In the second case he fears that he doesn’t know the answer but he hopes that he might answer it later. In the third case he experiences distress. After the completion of the test he is provided with the result mark. If the mark is passing according to the first and second case the student experiences satisfaction, joy, pride and gratification. Otherwise he experiences negative emotions. Thus, the current student’s emotional state is dependent on the educational event that occurs in the specific period of time and it is comprised of the contemporary student’s emotions.

Let us consider now another example. An Extroverted student’s current emotional state is judged as positive because he experiences emotions of joy, satisfaction and gratification. This state has been determined by an initial dialogue with the system. According to the parameter of the intrinsic student’s characteristics, this type of student has a strong probability to preserve these emotions until the next educational event. On the other hand, the transition probability reinforces this estimation. Consequently, we presume with great confidence that there is no any reason for the status of emotions to be changed. Let us assume now, that in the following period of time the student is provided with a multiple choice test that he has to fill. Therefore, the next educational event is related
with the student’s learning goal to accomplish this task. During the completion of this test the student can be experienced a wide range of emotions according to his type of personality and the progress of his effort. For instance, in case that a Neuroticism student found difficult to deal with some questions of the test, comparing to the Extroverted student he might be experienced more probably the emotions of frustration or fear because of failing. Taking into account the $P_m$ and the $P_n$ in combination with the progress of the task and the interaction time as well, we can predict these emotions and offer to the student the appropriate help. To a further step an Openness student experiences the emotion of hope because he wants to achieve a passing test score and believes that his desire could be satisfied. In case that his aspiration is fulfilled, the student according to the OCC model will experience the emotions of satisfaction, joy and pride. Therefore, his emotional state will be positive. In other case, he will experience the opposite emotions of disappointment, distress and shame. The confirmation of this speculation will be come to light by the tracing of the decision tree according to the corresponding production rules.

### 6 Experimental Study and Results

In order to evaluate our proposal and to validate the exactitude of MENTOR’s Affective Module prediction, an experiment was conducted with forty-three participants. The participants were all students in the field of computer science and their age was between eighteen and twenty-five years old. The students were given with the NEO-PI-R personality test [3] in order for their personality to be identified. According to this test they were five students who belonged to the Openness category, nine to the Conscientiousness category, sixteen to the Extraversion category, ten to the Agreeableness category and three to the Neuroticism category. Every student had the opportunity to interact with a pre-selected course of MENTOR ((basic concepts of AI) for thirty minutes. Then taking the learners’ responses into consideration and examining the log files of the system we were provided with the results that are shown in the Table 1.

![Figure 4: The accuracy of predictions of the learners’ emotions according to their personality.](image)

#### Table 1: Experimental results

<table>
<thead>
<tr>
<th>Student’s Personality</th>
<th>MENTOR’S Correct Predictions</th>
<th>MENTOR’S Incorrect Predictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Openness</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Conscientiousness</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Extraversion</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Agreeableness</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Neuroticism</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>32</strong></td>
<td><strong>11</strong></td>
</tr>
</tbody>
</table>

From the analysis of the above table we can infer that the percentage of MENTOR’s correct predictions is about 74%. Although these preliminary results are hopeful, there is still need for further research in order to improve our model and to establish a higher level of its prediction accuracy.

In figure 4, the categories of the students’ personalities and their corresponding prediction values are demonstrated in a graphical way. From this diagram we can easily draw the conclusion that for the categories of Openness and Neuroticism, which were appeared less frequently in our experiment, MENTOR had better and worse accuracy respectively in the prediction of their emotional states.

### 7 Conclusions and Further Research

In this paper we introduced an Affective Module which is responsible for inferring learner’s emotions and providing them with the appropriate affective tactic. The Affective Module is integrated in MENTOR which is a WBES with the aim of providing personalized distance learning in an affective way. The elicitation of emotions is based on a formal representation of emotions using an appropriate designed ontology and it is achieved by a combinational probabilistic machine learning method. We also presented some cases in order to exemplify, how the elicitation of emotion is performed. An experiment has been conducted as well with the aim of evaluating MENTOR’s Affective Module performance and has been presented in detail in the previous section. The preliminary experimental results are encouraging for the further development of the proposed model. The main purpose of the MENTOR, except from the recognition of emotions, is to create and / or preserve a positive mood in the student, since this is a crucial factor for the learning process. The implementation of the MENTOR has been done using the PHP5 language supported by Apache HTTP server 2.2. At this time we have implemented twenty different affective tactics. The designation of these tactics has taken into account the professional opinion of teachers and psychologists.
In advance research we are intending to improve the accuracy of our system in order to be capable of recognizing more emotions and more complicated emotional situations. When the integration of the MENTOR will have been completed, we plan to keep running the experimental study conducting a web evaluation in order to testify its reliability more precisely, so that the accuracy of the inferred emotions will be improved.

8 References


