A cognitive theory for affective user modelling in a virtual reality educational game *

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Abstract – *The educational community in general considers computer-assisted learning to be very beneficial. As a result, numerous new educational software applications are being developed. An educational application can become very effective if it is adaptive and individualised to the student. However, one important aspect of students that has been overlooked so far, and should be included in such individualisation models, is students' behaviour and emotional state that affects their learning. This paper describes how system observations of students' behavioural characteristics, during their interaction with an educational application, may provide important evidence about students' emotions while they learn. The information collected from these observations mainly concerns students' behaviour while using the application, combined with students' reactions and responds to questions depending on the correctness of their answers. The system's inferences about students' emotions are used to adapt interaction to each individual student's needs taking into account their character and mood.*

Keywords: Virtual reality, Educational game, Affective user modelling, Intelligent Tutoring Systems.

1 Introduction

Educational methods and applications constitute a field of continuous research around the world. The scientific community in general has acknowledged the need for a high degree of adaptivity and dynamic individualisation to each student that educational applications should provide. To this end, Intelligent Tutoring Systems (ITSs) have made significant contributions. It is simple logic that response individualised to a particular student must be based on some information about that student; in ITSs this realisation led to student modelling, which became a core or even defining issue for the field [4].

One aspect of students that plays an important role in students' learning, and has been overlooked so far is affect. Due to the importance of how people feel on their cognitive processes [7] the need for affective user modelling is clear. This automatically leads to the conclusion that student models should include information about the students' emotional state that affects their learning. Such affective modeling components can improve educational software and allow it to provide more adequate help for the students [13].

For the purposes of educational software that addresses affect, our application is an Intelligent Tutoring System (ITS) that operates as a virtual reality game. The VR- environment of the game is similar to the commercial virtual reality games. Such gaming applications, which typically provoke a wealth of emotions to users, can become an advanced test bed for affective states. This paper extends previous work done ([15], [16]) on educational virtual reality games by adding affective reasoning to the user-modelling component of the game. Thus the paper describes how system observations of students' behaviour while they interact with an educational application, may provide important evidence about students' emotions while they learn. The information collected about each student is evaluated by using parts of the Ortony, Clore & Collins (OCC) theory [10] about the cognitive structure of emotions.

2 Related work

The great popularity of software games among children and adolescents may also be exploited for the purpose of education. In particular virtual reality games constitute a very promising mean of developing more attractive educational applications. Papert [11] notes that software games teach children that some forms of learning are fast-paced, immensely compelling and rewarding whereas by comparison school strikes many young people as slow and boring. As a result, many researchers have developed games for educational purposes (e.g. [2], [9]). However, most of these applications do not take into account the affective states of individual students for the adaptivity of tutoring.

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The latest scientific findings indicate that emotions play an essential role in decision-making, perception, learning and more. They influence the very mechanisms of rational thinking. Not only too much, but also too little emotion can impair decision-making. According to Picard [12], if we want computers to be genuinely intelligent and to interact naturally with us, we must give computers the ability to recognise, understand, and even to have and express emotions.

Toward this direction, we have devised a mechanism for the automatic collection of probabilistic information of student affective states that our virtual reality educational application can use. This information is used in conjunction with information on student answers' results, to generate interventions that improve learning without compromising engagement. The affective information includes many characteristics of each student's behaviour and possible emotional state, and can provide useful guidance to the systems' provision of help and advice.

Affective user modelling is a rather new research area, therefore only a few computational modes of user affect have been devised to date. Similarly to our application, there are other educational applications that are based on the OCC theory and are discussed in [1], [3] and [6]. However, unlike our research, none of these applications refers to virtual reality games, which involve intense emotional experiences and provokes a wealth of emotions to users.

3 Virtual reality game

What we have created is an educational application for teaching English orthography and grammatical rules, which operates as a virtual reality game. This ITS-game is called VIRGE (Virtual Reality Game for English). In particular, VIRGE integrates the VR-game with the reasoning of an ITS. Students have the opportunity to play a 3D game, similar to the commercial ones, which enables them to learn while playing.

VIRGE invites the culture of computer games for creating a language tutoring system that can be very engaging, motivating and cross-cultural. In the case of language tutoring systems the use of computer games may additionally provide a cultural internationalisation and wide acceptance of these systems. The environment of a game plays a very important role for its popularity. Griffiths [8] found that the machine's "aura" typified by characteristics such as music, lights, colours and noise was perceived as one of the machine's most exciting features for a large part of the population questioned.

The environment of VIRGE is similar to that of most popular virtual reality games, which has many virtual theme worlds with castles, corridors and dragons that the player has to navigate through and achieve the goal of reaching the exit. The main similarity of this ITS with computer games lies in their use of a 3D-engine. However, VIRGE unlike commercial computer games of this kind is not violent at all and is connected to an educational application. In VIRGE one must fight one's way through by using one's knowledge. However, to achieve this, the player has to obtain a good score, which is accumulated while the player navigates through the virtual world and answers questions concerning English spelling. These virtual worlds look like the one in Figure 1.

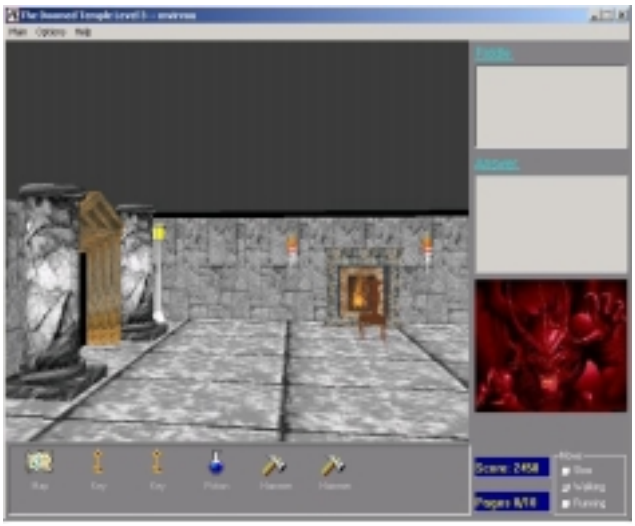

Figure 1. Virtual worlds of learning

As you can see in figure 1, part of the adventure of the game is the variety of inventory objects that the student can accumulate during the game and make the game even more attractive. There is map that every player has access to, and is an essential part of the game. The map shows an overview of the structure of the world, and is very useful for the navigation of the players in the world. Additionally there are other objects with useful functions including keys, potions, hammers, teleports and books.

Another part of the adventure of the game is that the player may come across certain animated agents. There are three types of animated agent, the advisor, the guard (who acts as a virtual enemy) of a passage and the student's companion. The animated agent who acts as an advisor, has the form of a female angel illustrated in Figure 2, and appears in situations where the student has to read new parts of the theory or has to repeat parts that s/he appears not to know well. In addition, virtual advisors are responsible for showing empathy to the students and help them in managing their emotions while playing and answering questions. The game itself may motivate students but it may also cause disappointment and

frustration each time a student does not perform so well as s/he would like or expect.

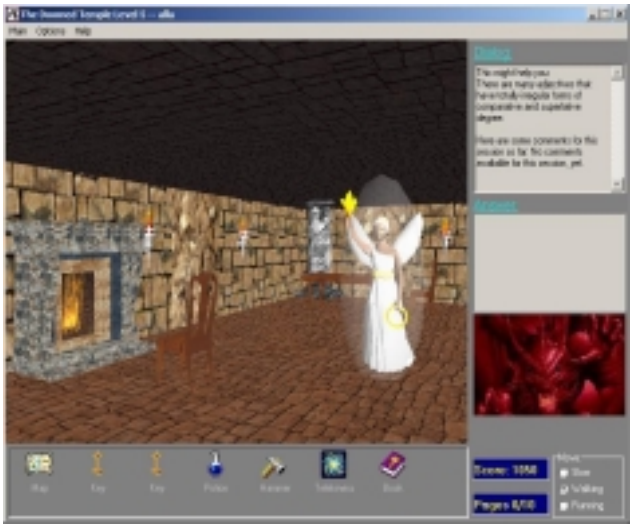

Figure 2. Virtual advisor agent

The virtual enemy agent is a dragon guard outside every door in the virtual worlds of the game that opposes himself as an obstacle on the student's course during the game. This agent is illustrated in Figure 3 below. This animated dragon agent asks a question and the student thinks and answers it.

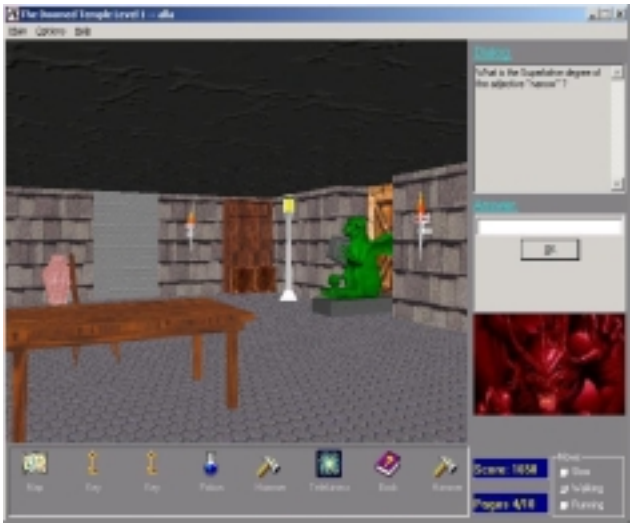

Figure 2. Virtual enemy agent

As we mentioned above the animated agent who is acting as a virtual enemy is responsible for asking questions to students. These questions constitute tests relating to the factual knowledge of the domain and have been constructed during the authoring process. All tests are part of the story of the virtual reality game. Tests may consist of questions about the English grammar of the following types:

1. Spelling questions.
2. Plural form of nouns.
3. Comparative and superlative form of adjectives.

Finally the virtual companion, who has the form of an elf, appears in cases where the student has given an answer, either correct or wrong, or has made a mistake repeatedly. Then the virtual companion appears, and makes some remarks in a casual way as if a friend was talking to the student. The existence of the virtual companion has been considered quite important by many researchers for the purpose of improving the educational benefit of tutoring systems and promoting the student's sense of collaboration.

4 Affective user modeling

Our educational application takes into account the history of answers of students and constructs a student-model for each one of them. It also monitors closely the actions of students, and it updates the individual student model for every student-player while they play the game. Additionally it generates individualised instruction and advice for students based on their student models. The student characteristics that are being modelled concern the knowledge level of students (answers' results - errors) as well as their behaviour while learning (user actions/ characteristics), which can be connected to their emotions.

For the purposes of finding out which aspects of the students' emotional state in relation to their performance in the educational game could be modelled, we conducted an empirical study. In this study, computer logging was used to record students' actions while they interacted with the application in a similar way as in [5] and [14]. Through computer logging the system may continuously collect objective data for further analysis and interpretation without interfering with users during their interactions with the system. The collected user protocols were passed on to 5 human experts who were asked to observe students' actions while they played the game and to note down what the students were likely to have felt. As a result, the experts had distinguished between different characters of students and assessed their emotions in relation to the students' characters and correctness of their knowledge.

Taking into account the results of the empirical study, the educational game uses as evidence on students' characters and emotions several actions that relate to typing and mouse movements. Time has played a very important role in our measurements. There are many inferences that can be drawn for the students' feelings and reactions depending on the time they spend before and after making some actions. Some examples of inferences

based on observations on time spent for various activities are the following:

- The *time* that it takes to the student to answer a question. This measures the degree of *speed/ haste* of the student.

- *Pausing time after a system's response*. The time the computer is left idle after a response to the student is used to measure the *degree of surprise* that the response may have caused to the student.

In addition, certain patterns of actions are used to show aspects of the students' cognitive and emotional state. Some examples of students' actions that are used as evidence are the following:

- *The number of times that a student presses the "backspace" and "delete" button while forming an answer*. This evidence is used to measure the *degree of certainty* of the student concerning a particular answer; the more times the student presses "backspace" and "delete" the less certain s/he seems to be about the correctness of his/her answer.

- *Mouse movements without any obvious intent in the virtual reality space of the game*. This evidence is mainly connected to the *degree of concentration* or *frustration* of the student; the more mouse movements without any obvious intent, the less concentrated or the more frustrated the student is. The exact interpretation depends on the context. For example if the mouse movement without any obvious intent occurs some time after the student has been asked a question then it shows frustration since the student does not probably know how to answer.

All kinds of evidence are used by the system to adapt its interaction with the user. The intensity of an emotional characteristic, either positive or negative, is very important for the selection of the appropriate advice for the user. The combination of such characteristics can provide information about the general mood of the student and lead to affective computing. The OCC theory of emotions suggests that for the purpose of finding out if an emotion really occurred to an individual there is a need for the specification of a specific value that is called the threshold value. If the potential value of an emotion is lower than the threshold value then the individual is not considered to experience the emotion. Otherwise the intensity of the emotion experienced is the difference between the potential of the emotion and the threshold value. An example of the calculation of the intensity of a JOY emotion according to the OCC theory is shown below.

IF (JOY_POTENTIAL) > (JOY_THRESHOLD) **THEN**
SET (JOY_INTENSITY)= (JOY_POTENTIAL)–(JOY_THRESHOLD)
ELSE
SET (JOY-INTENSITY) = 0;

In our case, we have used the OCC theory to find out which of the characteristics of each student, among the ones that are measured, have a value that is significant enough to play a role to his or her emotional state. While performing affective student modelling in the educational game, there are no emotions as such but rather behavioural characteristics related to emotions. For example, as explained above, in some cases the behavioural characteristic of mouse movements without any obvious intent is connected to the emotion of frustration. Consequently, behavioural characteristics cannot be intense as such but rather they can be significant. As a result, in our adaptation of the OCC theory in the educational game, the potential value and the intensity of an emotion that are mentioned in the OCC theory are replaced in our case with the value and the significance of a behavioural characteristic respectively.

Our application calculates the threshold value of each behavioural characteristic, by taking into account the mean value and the standard deviation value of each behavioural characteristic for each individual student. This decision was based on the fact that, in order to find if a value of a behavioural characteristic is significant, it is important to know if it is out of its usual bounds for the particular student. For example, one particular student may generally be very slow in typing his/her responses to the system whereas another one may be very fast. For these two students the threshold value of the pausing time needed for the system to give a "surprise" interpretation is different and depends on their usual behaviour. Then by using these thresholds of the behavioural characteristics, the system is able to find the significance that a value of a characteristic has. The system collects information for all of the characteristics of the student that have been included in the affective state representation. This information might either be positive or negative but either way can give evidence for the system to provide more detailed assistance depending on a possible affective state of the student.

5 Conclusions

In this paper we have described how evidence from the students' actions using the keyboard and the mouse, may be combined with evidence on the student's knowledge of the domain being taught for drawing inferences for the student's emotional state. Such inferences may be very helpful for adapting the system's advice on the needs of each individual taking into account both, his/her knowledge state and mood.

This information is collected during the interaction of the students with an educational application. Our educational application is a virtual reality game, which provides an ever more emotionally demanding environment. Such environments typically provoke a wealth of emotions to users and can constitute an advanced test bed for our research.

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