Learning and Forgetting Aspects in Student Models of Educational Software

Maria Virvou, Konstantinos Manos

Department of Informatics
University of Piraeus,
Piraeus 18534, Greece
mvirvou@unipi.gr; konstantinos@kman.gr

Abstract

In this paper we describe the part of the student modelling process of an educational application that keeps track of the students' learning and remembering facts that are taught to him/her. For the purposes of this process we have adapted and incorporated principles of cognitive psychology into the overlay technique that is used in the system for student modelling. As a result, the educational application takes into account the time that has passed since the learning of a fact has occurred and combines this information with evidence of the user knowing or not knowing something. This process gives the system an insight of what is known and remembered and what needs to be revised and when. In this way the system may dynamically adapt the content of each lesson to the specific needs of each individual student at a particular time.

1 Introduction

Since Information Technology has been so widely spread and offered its services to many domains and disciplines, it has also been widely acknowledged that it can be very useful for assisting education. To this end many educational software researchers employ several means of computer technology to improve the presentation, the structure and reasoning abilities of educational software. One important goal has been the improvement of attractiveness and aesthetics of educational applications based on multimedia, virtual reality etc. However, on the other hand, multimedia educational products are often criticised that they do not support the learner well nor exploit the capability of the medium (Laurillard 1995, Montgomery 1997, Moore 2000). From this point of view, the incorporation of a student modelling component into educational software may be quite important for rendering the system more adaptive to the student's learning needs, abilities, weaknesses and knowledge.

This paper describes the enhancement of a Virtual Reality educational game, by adding a module that could measure-simulate the way students learn and possibly forget through the whole process of a game-lesson. The virtual reality game is called VR-ENGAGE (Virvou et al. 2002) and teaches geography. In particular, we are going to describe a student modelling process that keeps track of what a student is being taught and will actually remember after the end of the lesson. This is achieved by the adaptation and application of models of cognitive psychology to the particular circumstances of the educational software application.

2 Student Modelling in the Educational Software Application

The educational software application aims at teaching students in a motivating way. Therefore teaching and testing takes place in the environment of a virtual reality game. Indeed, recently researchers in educational software point out the virtues of computer games relating to children and adolescents' education. For example, Muntaz (2001) notes that a range of cognitive skills are practised in computer game playing given the sheer number of decisions children make as they weave their way through various games.

In VR-ENGAGE the ultimate goal of a player is to navigate through a virtual world and find the book of wisdom, which is hidden. To achieve the ultimate goal, the student-players have to be able to go through all the passages of the virtual world and to obtain a score of points, which is higher than a predefined threshold. While students navigate through the virtual world they meet several animated agents that either show them parts of the lesson theory or ask them questions that the students have to answer. The total score of a player-student is the sum of the points that the player has obtained by answering questions.

The system also has the ability to adapt teaching to the specific needs of each student so that it may maximise the amount of knowledge that the student learns. For example it may dynamically select which part of the theory the student is going to see and when. For this purpose there is a student modelling component that keeps track of what the student has already seen (and when s/he saw it), what the student seems to have learnt given his/her answers to questions and what the student is likely to remember by the end of the lesson. This information is stored in the long term student model to be used in subsequent lessons.

Student modelling in VR-ENGAGE is based on the overlay technique. The overlay model was invented by Stansfield, Carr and Goldstein (1976) and has been used in many early user modelling systems (Goldstein, 1982) and more recent systems (Matthews et al. 2000). The main assumption underlying the overlay model is that a user may have incomplete knowledge of the domain. Therefore, the user model may be constructed as a subset of the domain knowledge. This subset represents the user's partial knowledge of a domain and thus the system may know which parts of the theory the user knows and which s/he does not know. However, as Rivers points out (1989), overlay models are inadequate for sophisticated modelling because they do not take into account the way users make inferences, how they integrate new knowledge with knowledge they already have or how their own representational structures change with learning. One additional problem with the overlay technique is that it assumes for the student an "all or nothing" knowledge of each part of the domain (either a student knows something or not).

The overlay technique has to be used in conjunction with inference mechanisms about the students' knowledge. The inference mechanisms that have been employed so far have been mainly based on students' actions in assessment tests that show evidence of the students' knowing or not knowing something. However, even in cases where the student shows evidence of knowing something at a particular time, s/he may forget it after a while. Therefore in our research we take into account what parts of the theory the student has been shown, how often this has happened and what s/he is likely to remember. Therefore the overlay technique is extended to include degrees of knowledge for each fact. Each degree represents the possibility of a student knowing and remembering something given the time this was learnt. For this purpose, we use a forgetting model.

There are two popular views of forgetting (Anderson, 2000). One, the decay theory holds that memory traces simply fade with time if they are not "called up" now and then. The second view states that once a material is learned, it remains forever in one's mental library, but for various reasons it may be difficult to retrieve. These theories may seem to be "conflicting", but when someone has "forgotten" something, there is really no way for us to tell whether it has been completely removed from his/her mental library or it is very (almost impossibly) difficult for him/her to retrieve it. For our study, both theories have practically the same meaning; if a student finds it hard to remember a fact that s/he has learnt (either due to memory fading or difficulty of retrieval) then the learning process was not that good and should be modified.

A classical approach on how people forget is based on research conducted by Herman Ebbinghaus and appears in a reprinted form in (Ebbinghaus, 1998). Ebbinghaus worked for a period of one month and showed that memory loss was rapid soon after initial learning and then tapered off. In particular, Ebbinghaus' empirical research led him to the creation of a mathematical formula which calculates an approximation of how much may be remembered by an individual in relation to the time from the end of learning (Equation 1).

$$b = \frac{100 * k}{(\log t)^c + k} \qquad (1)$$

In Equation 1:

- t: is the time in minutes counting from one minute before the end of the learning
- b: the equivalent of the amount remembered from the first learning. As it is evident from the logarithmic nature of the formula, b lowers greatly at the beginning and starts to stabilize after time passes on.
- c and k : two constants with the following calculated values: k = 1.84 and c = 1.25

Linton (1979) also conducted research on retention of knowledge and worked for a period of six years. Linton's results were similar to Ebbinghaus' results. Finally, Klatzky (1980) also reports the results of a study that consisted of experiments on retention. These experiments involved repetitions of a memorised list of words after a pre-specified break length, typically up to few days. This study showed that memory decay is a power function of the break length. For example, subjects forget 55% of the words within a six hour break time and 80% percent within 72 hours. However, these results are very close to Ebbinghaus results. Indeed, if Ebbinghaus' formula was used, one would find that subjects forget 60% of the words within a six hour break and 75% within 72 hours. Such differences in the results have little importance for the purposes of the incorporation of a forgetting model in the educational application. Therefore Ebbinghaus' mathematical formula has been used in VR-ENGAGE to give the system an insight about the students' learning and forgetfulness.

In our model there is a database that simulates the mental library of the student. Each fact a student encounters during the game-lesson is stored in this database as a record. In addition to the fact, the database also stores the date and time when the fact was last used along with a numerical factor describing the likelihood of the student's recalling the given fact. The smaller the factor the less likely it will be for the pupil to remember the fact after the end of the game-lesson.

Our research goal is to render the educational game more effective in teaching the student. This will happen if after the course the student actually ends up with many facts with high factors in his/her mental library. To model that, we assume that the student has a blank mental library on the subject being taught; meaning, that during the first lesson there is nothing in the mental library of the student to be retrieved.

3 Learning a new fact

While the student plays the educational game s/he encounters a "tutor" that provides him/her with a piece of information to be taught (Virvou et al., 2002). This is the first encounter of that information so it is added to the memory database. The data saved in the database are:

- **ID**: It is a string ID of the fact being taught
- **TeachDate**: It is the date and time of the first occurrence
- **RetentionFactor(RF)**: a number showing how likely it is for the student to actually remember the given fact after the end of a "game lesson"

When a fact is inserted in the database, the TeachDate is set to the current date and time, while the RF is set to a base number equal to 95. Taking as a fact that any RF bellow 70 corresponds to a “forgotten” fact, using the Ebbinghaus’ power function we may calculate the “lifespan” of any given fact. The RF stored in the “mental” database for each fact is the one representing the student’s memory state at the time showed by the TeachDate field. Thus, whenever we need to know the current percentage of the fact that a student remembers, the equation 2 is used.

$$X\% = \frac{b}{100} * RF \quad (2)$$

Where:

- b: is the Ebbinghaus’ power function result (Equation 1), setting t=Now-TeachDate
- RF: is the Retention Factor stored in our database

4 Recalling – Using a fact

During the game, the student may also face a question-riddle (which needs the “recall” of some fact to be correctly answered). In that case the fact’s factor is updated in accordance to the student’s answer. For this modification an additional factor, the Response Quality (RQ) factor, is used. This factor ranges from 0 to 3 and reflects the student’s answer’s “quality” in the way illustrated in Table 2.

Table 2: Response Quality Factor reflecting the student’s answer’s quality

RQ	Description	Modification
0	No memory of the fact	RF’ = X – 10 TeachDate = Now
1	Incorrect response; but the student was “close” to the answer	RF’ = X – 5 TeachDate = Now
2	Correct response; but the student hesitated	RF’ = RF + 10
3	Perfect response	RF’ = RF + 15

Table 2 illustrates the formulae used to modify the RF of the correspondent fact, depending on the RQ value. In the formulae used:

- X is the value calculated using Equation 2
- RF\` is the new Retention Factor value
- RF is the old Retention Factor value

In the cases where the RQ is 0 or 1, the student has a difficulty remembering a fact that has already been taught to him/her. Thus, in these cases the TeachDate is reset so that the Ebbinghaus’ power function is restarted. This will generate a rapid loss of memory in the beginning and will stabilise later on. By lowering the RF (by ten or five) even for a student with very strong memory, it gives the fact a “lifespan” of a couple of minutes, thus it is necessary for the game to repeat the teaching process of the given fact if it wishes the student to remember it.

5 Conclusions

In this paper, we have shown how principles of cognitive psychology have been used by the student modelling process of an educational application. This is done so that the system may gain an insight of what students remember from the course material that has already been taught to them. For this purpose, the system takes into account how much may be remembered by an individual in relation to the time from the end of learning. In addition, it takes into account what the student has been able to remember from the material taught as this has been recorded in his/her performance in tests. This information is used by the system to adapt the teaching process accordingly. Depending on what a student remembers or not the system proceeds in presenting new course material or repeats certain parts of the course material that has already been taught. In this way, the educational software application may become more personalised and adaptive by responding appropriately to each individual student's needs regarding the way the course material is being taught to him/her.

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