An example of an algorithm to add the use of intelligent tutoring systems to serious games for cognitive enhancement

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Abstract

The spread of educational technologies, the study, and design of new software and applications for mobile devices increasingly connected with systems that collect data, is producing enormous quantities of information. The great data collection potential of these applications can be a mine of information that can help psychologists, educators and pedagogues to understand how students learn and, moreover, can help learning researchers to develop more effective educational methodologies, not only for students who have typical cognitive development, but also for students with learning difficulties. In this article we want to explore the potential of these new tools and understand how they can be integrated precisely in those softwares that support weakened learning processes, i.e., how an intelligent tutoring system (ITS) can support the selective attention processes of a child with attention deficit hyperactivity disorder, or how he can guide specific training on executive functions. In this article, we propose an example of an algorithm to create a simple ITS to be used in the development of software for cognitive rehabilitation.

Keywords

intelligent tutoring systems, education, rehabilitation

1. Introduction

The history of artificial intelligence has known Intelligent Tutoring Systems for some time and, over the years, hand in hand with the evolution of technological systems, the algorithms have become increasingly more precise and performing. An intelligent tutoring system (ITS) is a computer system that aims to provide immediate, personalized instruction or feedback to students, usually without requiring the intervention of a human teacher. ITS has the common goal of enabling learning in a meaningful and effective way using a variety of information technologies. There are many examples of ITS used in both formal education and professional settings, where they have demonstrated their capabilities and limitations. There is a close relationship between intelligent tutoring, cognitive learning theories and design, and research is underway to improve the effectiveness of ITS. An ITS typically aims to replicate the demonstrated benefits of one-on-one, personalized tutoring, in settings where students would otherwise have access to one-to-many instruction from a single teacher (e.g., classroom instruction) or no teacher (e.g., online homework).
The first developments of the introduction of software programs, as auxiliary means in educational learning, were formalized within the framework of the CAI (Computer Aided Instruction) project. These programs used a decision tree to guide the student from one session to another, depending on the answers given [Urban Lurain 1996]. However, they did not take into consideration the diversity of the students and their specific needs, backgrounds, or history. CAI programs, therefore, were not able to adapt to the specific way of acquiring knowledge that the student had and were not able to provide the individualized attention that instead the human tutor ensured [Bennett 1997]. Recent developments in

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research in the field of artificial intelligence have led to a new field of application, which takes the name of Intelligent Tutoring System [Burns & Capps 1998]. The basic feature of these systems is to consider each student as unique, creating a student model capable of recording preferences and progress during the cognitive process [VanLehn 1998]. In addition, what increases its effectiveness in teaching is its ability to adapt to the characteristics of the student. To do this, the system must try to get as close as possible to the student's way of thinking. In other words, it must manage the different aspects of vagueness present in the data expressed with real words. ITS are often designed with the goal of providing access to a high-quality education for all students. Today, intelligent tutoring systems are widely used in schools and universities, the data collected is then used to improve the learning experience of students. Some studies have experimentally established and valued the benefits that students can derive from the use of these tools, but what is even more important is that these systems are increasingly used to collect large quantities of "Big Data", often available free of charge and which they can be used to enhance our understanding of student learning and create a better, more interactive, engaging and effective education. In recent years, a number of types of interactive educational technologies have also become important and widely used, not only scientific simulations and virtual laboratories, but also and above all educational games developed with touch interfaces through a tablet and tangible and physical interfaces. The development of new technologies and the unstoppable growth of increasingly flexible and effective distance teaching-learning models, based on the use of the technologies themselves, are determining the birth of a new society that we can define as a "cognitive society". The COVID-19 pandemic has determined that the role of teachers and learners, within the training process, was forced to change radically since, the first, they found themselves acquiring new and complex skills related to distance teaching, as well as the role of guiding the learning process of the students; the latter, on the other hand, have regained an active role that allows them to become real protagonists in the creation of new knowledge and new knowledge. In this context, the figure of the tutoring system assumes significant importance, the task of which is to support, stimulate, accompany learners in their training and help them develop superior cognitive skills, thanks also to the use of those tools which Donald A. Norman defines as “cognitive artefacts”: that is, new technologies.

2. General structure of an intelligent tutoring system

Personalization of instruction through the use of educational systems can significantly improve the student's learning process. So an ITS performs functions similar to those of a human guardian, emulating its decision-making process. It is able to manage a great deal of knowledge on a specific area, moreover it establishes, through an interface in natural language (or very close to it), an interview with the user: it makes deductions relating to the case study, according to the knowledge of the previously stored domain. To create a system that adapts to each individual student, we will have to be able to memorize every action and from this deduce the evolution of his "mental state". The representation of the current mental state of the student is called the "student model". In order to satisfy its purposes, an ITS must therefore have a modular structure. According to McTaggart [2001] the ITS are composed of four components that interact with each other in such a way as to put the student in relation with the knowledge of a predominant subject. This interaction allows the student to assimilate new knowledge and insert it into his mental scheme.
The components in question are:

The expert knowledge model: this module contains the explicit knowledge representation to be provided to the student expressed in the form of a model.

• The student model: interprets the answers given by the student by formulating hypotheses on the knowledge that allowed to produce these answers. This module must therefore maintain an individual model of the specific student under examination

• The pedagogical model: the model contains the expert knowledge on teaching strategies and teaching techniques. It is the module responsible for planning the presentation of topics.

• The user interface: This component controls the flow of communications to and from the user, translating the information from the representation language internal to the system into a language more easily understood by the student.

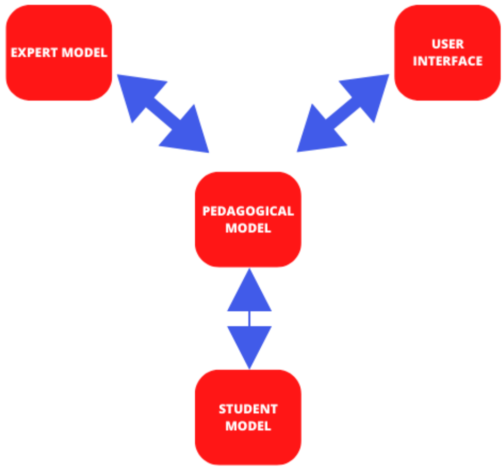

Figure 1: General architecture of an ITS system

2.1. Intelligent tutoring system classification of “student model”

The student model is the component of an intelligent tutorial system, which stores the current state of the acquired knowledge. One of the first attempts to build the model was the one experimented by Carbonell [1970], who used a semantic network to represent the domain of knowledge. However, the term "modeling student" comes from CAI research. Early attempts by the CAI were made to encourage individualized teaching through the use of student models. The first CAI systems, described by Self [1974], were characterized by the fact that comments and problems were not pre-memorized, but were generated dynamically. He divided CAI systems into two categories according to whether knowledge was acquired by implicit or explicit teaching.
The models of the current ITS can be classified according to the functions they perform or, more significantly for the current literature, by means of the respective ways of interpreting the information: processing or static models [Cancey,1986].
Self [1988] describes six main functions that student models must satisfy:

1. Corrective function
2. Computational function
3. Strategic function
4. Diagnostic function
5. Predictive function
6. Evaluation function

The corrective function: The corrective function: in this case the model must be able to identify the difference between what the student understood and the real concept, and then be able to remedy it.
The computational function: the model must broaden the knowledge of the learner, i.e. it must identify new areas in which the learner can be introduced, or refine his/her current knowledge. The strategic function: this function changes the teaching approach, modifying the current teaching with a higher level of teaching.
The diagnostic function: this function describes the analysis of the student's cognitive state. If, for example, the tutor wants to introduce a new topic and if the student model is not able to establish the

adequacy of the level of knowledge achieved, then it will have to be able to generate examples of a diagnostic type for the student to carry out.
The predictive function: the model uses this function to anticipate the effect of an action on the student. In other words, the model simulates the behavior of the student.
The evaluation function: this function provides an assessment of the learner's learning level. This requires the system to sort of aggregate the information it possesses. The student knowledge representation problem.
Early CAI systems supported corrective and processing functions but lacked diagnostic, strategy and prediction procedures. Processing models, called execution models, are able to simulate the process by which the learner solves a problem and can, therefore, perform the predictive function. Executable models are also called procedural [Brusilovsky 1994], as the elements of knowledge of the latter are usually represented by means of procedures. There are several ways to represent student information.Le tecniche comunemente usate sono:

- Modelli Overlay
- Modelli Overlay con estensione buggy
- Reti Bayesiane
- Logica Fuzzy

Overlay models are characterized by the fact that they consider the student's knowledge as a subset of the expert model's knowledge. The most important function of the domain model is to provide a framework for the representation of the user's domain knowledge using the overlay knowledge model. The key principle of the overlay model is that for each domain model concept, individual user knowledge model stores some data that is an estimation of the user knowledge level of this concept. The overlay model is powerful and flexible because it can independently measure the user's knowledge of different concepts. In the simplest (and oldest) form it is a binary value (known – not known) that enables the model to represent user's knowledge as an overlay of domain knowledge.
With this representation, an ITS will hand the student more and more material, until his knowledge matches that of the expert model. The disadvantage of this type of approach lies in the fact that it does not admit that students can be bearers of concepts that do not belong to the expert knowledge base. Thus an extension of the overlay model explicitly represents buggy (incorrect) knowledge that the student might have. The extended model allows a better management of the errors made by the student, bearing in mind that the fact that he may have a wrong concept is pedagogically wrong

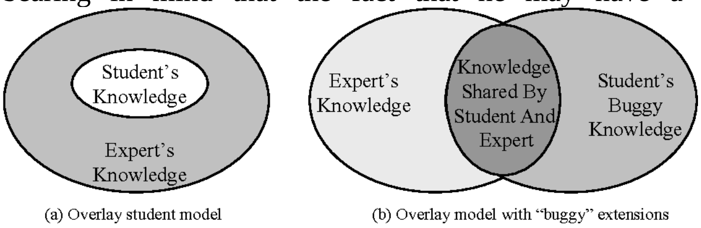

Figure 2: a) The Student Model Overlay; (b) The "buggy" student model

Another mechanism aimed at storing the student's knowledge is represented by Bayesian networks. These reason in terms of probabilities about the state of knowledge of the student provided by his interaction with the tutor. Each node in the network contains a probability, which indicates the degree of likelihood between what the student is knowing and actual knowledge.

3. Cognitive rehabilitation and Intelligent tutoring systems

Cognitive training consists of the repeated practice of activities designed and structured to improve specific cognitive skills, such as memory, language, attention and executive functions. These activities can be performed under supervision or from home and can be configured as a "paper-pencil" activity or computerised. In particular, computerized cognitive trainings have several advantages since they allow a great variability of the stimuli used and can automatically adapt to the patient's performance.

Furthermore, in the field of research, they allow a high standardization of tasks and the automatic recording of some data (accuracy and response times) useful for patient's performance improvements. A growing interest about alternative methods for the assessment and training of learning and of cognitive function in children with neurodevelopmental disorders is emerging. Today technology is considerably advancing, and the gamification is giving an important contribution in making the interventions more engaging. However, sometimes a “top-down” design process creates mismatches between technologies and both therapists and children's need. The same situation also occurs for cognitive training to counteract the cognitive deterioration of elderly people or people with dementia. Today a widespread approach involves the use of video games to improve cognitive performance in the elderly. In particular, "serious games" are used, i.e., games primarily designed to provide a learning experience, educational games or commercial videogames not specifically designed for the elderly population and mainly composed of action games. The advantage of this approach is that it is cheap and that it is a playful and pleasant activity potentially allowing for greater adherence to treatment by the elderly population. For these reasons, many software and many serious games have been developed in recent years. The limit that all these digital systems have encountered has been the scarce adaptation of the games to the patient's needs, to his cognitive level, his preferences, his general abilities.

4. Algorithm description

We are working on an algorithm hypothesis for ITS that can ensure that the most personalized exercise possible can be provided to the person who is playing the game. These systems have been defined as Artificial Psychological Agents, they consist of an artificial system immersed in an environment, equipped with a sensory system, a control system, and a behavioral system. (Miglino 2019). The agent acts autonomously to modify his environment of action and the relationship between himself and the environment itself. The artificial agent is defined as "psychological" when its structure and/or functioning incorporates/simulates some cognitive, affective, or socio-relational dimension/property. In the following image, we see a definition of our artificial agent and the units it is made of. The algorithm is initialized through an assessment, i.e., through a game session which determines the cognitive abilities of the subject, his sensorimotor abilities and his preferences. Subsequently this information will be sent to a database that collects all performances of the player. This information will allow central module of the ITS to choose, in the first instance, a series of other games to be provided to player, taking these games from the "DB Training" module. DB Training contains all the games divided by difficulty, by area of learning or by area of cognitive enhancement.

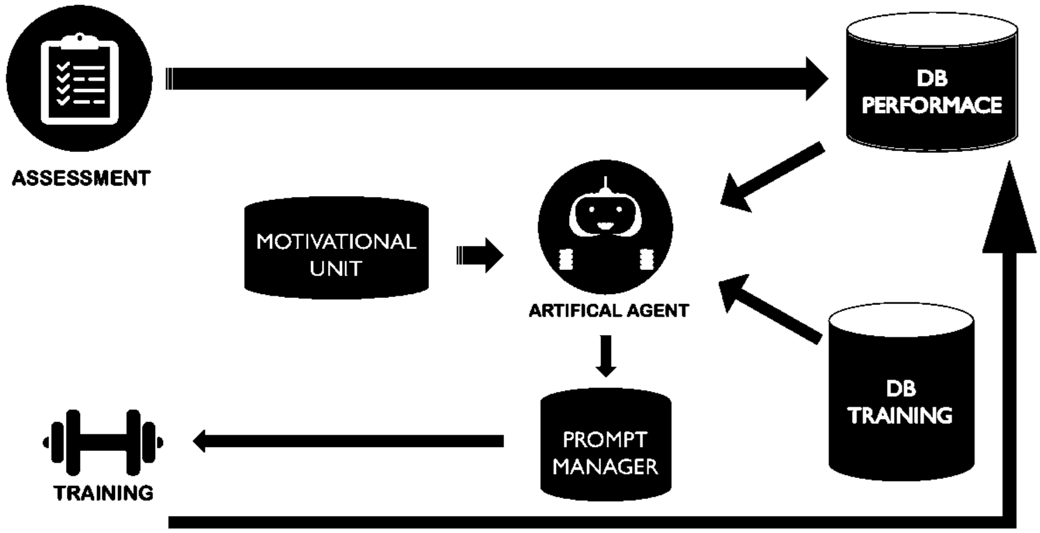

Figure 3: Algorithm description

At this point the game will be delivered and the agent, based on the scores obtained by the player, on the basis of the cognitive assessment and preferences, will be able to choose to use the "Motivational Unit" to enrich the game scenarios with more motivating elements for the player and will be able to use the "Prompt Manager" module to offer the player some help to amplify his permeances. As the player improves or worsens, the ITS will be able to provide aid based on the actual results of the training, thus offering a highly personalized cognitive enhancement experience.

5. Conclusions

This algorithm model is an explanatory simplification, the software model is more complex. Our folks are implementing this simplified version into software for learning enhancement and executive function training. In the future we will test the algorithm on a clinical sample to analyze the algorithm in a clinical setting.

6. Acknowledgements

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