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Fuzzy and MultiAgent Instructional Planner for an Intelligent Tutorial System

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ABSTRACT

This article presents some aspects in our research into the design of a Fuzzy and MultiAgent Instructional Planner belonging to an Intelligent Tutoring System (ITS), which has been designed as a tool for the reinforcement of the addition operation. The authors propose the combined use of both fuzzy and MultiAgent Systems. The fuzzy logic methodology is used to model the student's knowledge and the teaching strategy. Furthermore, the MultiAgent System implemented determines the learning objectives so as to provide the student with an efficient learning process. The fuzzy and MultiAgent Systems comprising the instructional planner were verified with the collaboration of experts in mathematics and in other areas of knowledge. The results obtained by the primary school children who used the ITS are also presented.

1. Introduction

The topic of this paper is the design and implementation of an instructional planner for an Intelligent Tutorial System (ITS) intended to reinforce the logical concepts of numbers, addition and subtraction as part of a primary school curriculum, though it can easily be generalized to other application domains.

Intelligent Tutoring Systems [1–3] were first used in the 70s as a way to provide greater flexibility to the learning strategy and to achieve better interaction with the user [4]. The aim of ITS is to capture the knowledge of experts to create dynamic interactions with the users, allowing them to make decisions, even those that may not have been anticipated by the experts.

The main advantage of ITS versus traditional tutoring systems is that they are more flexible in both their approach to the learning domain as well as in their adaptation to the student. In traditional systems, which contain a large amount of rules, and therefore of information, the student can find herself lost and improperly guided by the tutorial. It can also happen that since traditional tutorials do not adapt to the student, if she already has knowledge of the subject she will become bored if forced to inflexibly adhere to a sequence of activities whose concepts are already familiar to her. The opposite could also happen whereby the tutorial advances too quickly for a student who has not fully assimilated the basic concepts. The solution offered by ITS is the inclusion of several modules containing information about the student and the domain. In this way the tutorial, thanks to its flexibility and adaptability, can offer solutions to a wide range of users and benefit from the use of audiovisual resources (video, audio, animation, etc.) to motivate the student.

Keeping in mind that statement, In this paper we propose a sophisticated planning process at different levels of the ITS processing by decomposing the tutor module into two different components through the combined use of fuzzy logic and multiagent techniques, taking advantage of the benefits provided by each. Fuzzy logic is employed due to the usefulness of having a tool in the ITS for handling imprecision and that allows for knowledge to flow freely from the expert. There are various ways of modeling imprecision, but in most cases that imprecision is used to a small extent. The majority of methods for handling imprecision are probabilistic, though it is interesting to bear in mind that experts do not normally think in terms of probability, but rather in terms such as much, little, good, average, etc. An expert fuzzy system means that the system incorporates fuzzy sets and/or fuzzy logic into the reasoning process and/or into the representation of knowledge. The theories on fuzzy sets and logic are well established, having existed now for 25 years and applied in multiple control applications. Expert systems that feature fuzzy techniques have also been developed [4,5]. In the ITS, the fuzzy logic methodology is employed to model the uncertainty in the student's knowledge base and in the teaching strategy [4,6]. The use of a MultiAgent System, on the other hand, offers a great advantage in applications that are able to use distributed computing since the ability to divide tasks provides modularity and flexibility while reducing computing time [7,8]. Incorporating this technique into the ITS improves the objective learning strategy

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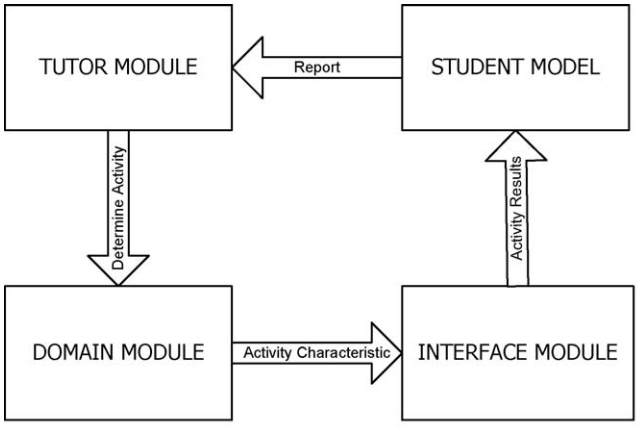

Fig. 1. Architecture of an ITS.

while at the same time decreasing the wait time in interacting with the user [9].

This paper is organized as follows. In Section 2 we describe the ITS architecture and domain. In Section 3 different methods for the implementation of instructional planners are enumerated. In Sections 4 and 5 we describe the two fundamental parts of the instructional planner: the fuzzy system and the MultiAgent System. Section 6 shows the results of the ITS validation. Lastly, the conclusions are presented in Section 7.

2. Architecture and domain of Intelligent Tutoring System

The tutorial will follow an individualized teaching process which consists of determining what the learning objectives are based on the students' predetermined characteristics. To this end, a series of activities will be devised for the students to perform so as to enable them to acquire the specified skills. The set of activities, therefore, will not be the same for all the students, but rather will depend on the characteristics of each.

The ITS uses a modular structure that lends itself to being reused in other application domains. Although mathematics was used as the application domain in this implementation of the ITS, it has been designed so as to enable its generalization to any other domain. Two key aspects make this generalization possible: the database-centered approach, which uses a database (DB) to store all of the system's static and dynamic information; and the design of the fuzzy and MultiAgent Systems used in the implementation of the Instructional Planner.

2.1. ITS architecture

It is possible to consider Intelligent Tutorial Systems as being comprised of following four modules (domain module, student model, tutorial module and interface module) [10] (Fig. 1):

- Domain module: This module contains the knowledge about the area of study. It contains the specific and detailed knowledge of the application domain as obtained from human experts. Every concept related to the learning objectives is described. In addition, the mechanisms for learning said concepts are specified. Therefore, for each student several tasks are specified. These tasks are chosen based on the learning objectives for this student. The student characteristics are obtained from the student's profile. Then, the tasks (for example motivation, presentation, evaluation or reinforcement) will be displayed to the student through the interface module.
- Student model: This module monitors the student's progress. It contains all the data and information on the student. These data are used to choose both the appropriate subsequent subject and the educational methodology or strategies. Basically it is possible to divide the model of the student into two fundamental components, the profile and the history. The profile indicates the personal characteristics of the student as related to their motor function, cognitive and psycho-social development. Variables that are considered in the profile are: chronological age, cognitive age, physical capacities (fine motor function, ocular contact, auditory capacity), cognitive development (short-term memory, attention, capacity to form concepts, capacity to group objects into significant categories, language and vocabulary development, understanding of words, capacity to react and initiative), interaction with the surroundings (connection with the surroundings, level of adaptation, participation in group activities, obtaining of information from the surroundings), personality (fear of failure, dynamics, hyperactivity or passivity), behavioral patterns (repetitive conduct, restricted conduct, stereotyped activities), preferences (colors, personal interest). The history covers those variables related to previous concepts that the student knows, as well as the progress exhibited (repeated exercises, omitted tasks, rate of progress between activities, learning style, etc.).
- Tutorial module or instructional planning: It controls the system. This module determines the education strategies so the system can adapt and improve the tutorial strategies based on the student. It must detect the level of the student, select the next activity to be carried out by the student, select examples, correct errors, etc.
- Interface module: Its objective is to display the subjects to the students. The interface can, depending on its design, make the user's interaction with the system more or less understandable. This can affect the acceptance level that the student has of the ITS.

2.2. Application of the proposed architecture

The educational objective of the ITS presented in this paper is the number concept and the objectives of sum and subtraction in Spain's primary education curriculum. Some objectives are presented simultaneously, while others are a prerequisite for their successors (Fig. 2). The result is four phases that the student has to cover successively. It is possible to advance or to backtrack based on the results of the execution of the activities by the student. Each of these phases will consist of objectives to be covered in parallel. These objectives are carried out through related activities. The activities of a single objective can be divided into several difficulty levels. When the student carries out the activities corresponding to each objective with a suitable passing grade, the student can progress to the following phase.

The phase-1 activities to be completed by the student are grouped into two difficulty levels, while those for the objectives corresponding to phases 2, 3 and 4 are grouped into three difficulty levels.

3. Tutoring module

The tutorial module or Instructional Planner makes the decisions in the ITS. The process of individualized education consists of determining the learning objectives considering the characteristics of each student. A set of tasks to be carried out by the student is devised so as to allow him to acquire the concepts. There will not be a standard set of tasks to be carried by every student, as these will depend on the characteristics of each. For each concrete stu-