

The consensus-based tutoring strategy selection in CAL systems

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ABSTRACT: The tutoring strategy selection is made in the environment of hypermedia scenes that presents knowledge in some domain. The knowledge may be presented in many different ways and human tutors may construct, out of these scenes, several tutoring strategies that present the subject at hand. This paper presents a method for consensus-based strategy selection in Computer-Assisted Learning (CAL) systems. The general idea of the method is based on the assumption that similar students (as for the history of their learning process) could have similar tutoring strategies in the following steps of knowledge acquisition. For each student, it is very difficult to find a single strategy that is completely suitable; it is more likely to find a group of students that are similar to some extent. It is assumed that their experience could be used to construct, by means of consensus, another completely new and as yet non-existing tutoring strategy.

INTRODUCTION

The selection of tutoring strategy is an integral part of the knowledge transfer process. The tutoring strategy influences the effectiveness of teaching by means of its speed and persistence of memorising information presented during this process, as well as the students' ability to use the acquired knowledge. Generally speaking, the tutoring strategy is some kind of combination of means and methods used in the whole didactic process to increase its effectiveness. The method is defined as rules and ways of organising the subject knowledge, while the means consist of different types of presentation media [1].

In traditional tutoring systems, it is mainly the teachers who prepare the tutoring strategy. By doing this, they are basing it on their subject and methodical knowledge, as well as their own experience. Usually, this strategy is not completely stable and quite often is modified during the didactic process, depending on the students' reactions. Direct teacher observations, test results, student questions and participation in different disputes can give a great deal of valuable information about the progress of the process, as well as provide the base for strategy modification.

In both Computer-Assisted Learning (CAL) and Distant Learning (DL) environments, system designers usually construct the tutoring strategy [2]. They often assume that taking into consideration several factors such as: subject area, learning material character and student profiles, it is possible to arrange material and adjust its form in such a way that it is the most convenient for each ordinary student (with the adequate profile) to acquire and broaden his/her knowledge. Unfortunately, this is usually far from being effective. Instead, the best strategy for every individual student should be found; of course, different strategies may be more effective for some

students than others. One possible way to overcome these problems is to develop several tutoring strategies and a mechanism that is able to choose a proper one for each didactic situation. These problems usually are considered in the context of Intelligent Tutoring Systems (ITS).

INTELLIGENT TUTORING SYSTEMS (ITS)

Research in the area of ITS began in the early 1970s. Its goal was to develop a computer-based tutoring system that would offer every individual student optimal conditions for his/her education by generating content and controlling its transfer. Each ITS consists of three modules, namely:

- A *domain module* has expert knowledge at its disposal, which may be represented in the form of facts and rules. This module has usually two basic functions: generation of tutoring material and testing student progress.
- A *student module* stores the current state of the students' knowledge in the domain as well as his/her history of the didactic process. This module cooperates with the domain module to test students' knowledge.
- A *teacher module* contains knowledge about different tutoring strategies and decides on the order of the presented knowledge, when examples should be delivered, etc [3].

However, ITS design generates several problems. Experience in expert systems is very useful with regard to domain and student modules, but the most difficult is the teacher module. Its design usually requires the application of non-formal pedagogical knowledge [4].

TUTORING STRATEGY SELECTION IN CAL SYSTEMS

Current research in human and machine tutoring suggests the selection of tutoring strategies should consider the following

issues: subject matter, cognitive differences, test scores, *trial and error* selection, student involvement, human tutor involvement [5]. The importance of each element is as follows:

- Subject matter represents what should be thought; different subjects require different types of tutorial strategies.
- Cognitive differences are very important in the individual tutoring of students.
- Test scores show tutors how the student acquires knowledge.
- *Trial and error* helps the tutor to test different tutoring strategies for different students and in different situations.
- Student involvement influences the tutorial discourse.
- Tutorial environments define the tutoring media delivered to the student.
- Human tutor involvement is necessary because tutoring could not be completely automated.
- Tutoring strategies of other similar students could help determine an optimal strategy.

Tutoring strategy selection should be deployed in the following situations:

- When change is encountered in the nature of the tutorial material during the didactic process.
- When students with different cognitive needs engage in the tutorial discourse.
- When the student's level of advancement reaches an appropriate level.
- When the test scores of a student are extremely poor or very good; the former shows that the chosen strategy has failed and the latter, in some situations, may suggest the student's perfect knowledge of testing procedures.
- Random procedures should be deployed if the system has little knowledge about student preferences or general profiles of the students.
- When the motivation of a student needs to be raised, it is important to give the student the opportunity to influence the strategy selection to engender a sense of didactic process control.
- When there is a change in the presentation method for other educational material.
- When human tutor involvement is necessary (often when there is a need for explaining a new tutoring strategy).

A CONSENSUS-BASED TUTORING STRATEGY SELECTION MODEL

This paper presents a consensus-based tutoring strategy selection system. It is assumed that there is a population of students who use this tutoring system. The system is designed to tutor students in different courses, which are divided into several parts. After, and sometimes during, each part, strategy selection takes place. After completing each part, students are tested and these test scores are used to influence the following selections in the tutoring strategy. Each tutoring strategy for each student, as well as his/her test scores, are stored and used in the consensus-based tutoring strategy selection model. Knowledge is presented to students in the form of sequences of hypermedia scenes that contain different media: texts, images, equations, audio and video. These scenes could not be further divided. Tutoring strategies contain sequences of these kinds of scenes plus different combinations of testing questions.

A general algorithm for strategy selection is presented in Figure 1 [6]. The selected tutoring strategy corresponds to part of a whole course that has didactic goals whereby achievement may be measured by means of test scores. The consensus-based tutoring strategy selections, which take place in a few places in the algorithm, are described in the following section. When automatically generating a sequence of scenes, it must be ensured that this sequence is consistent. In this method, some special logic formulas about its pre-conditions and post-condition are attached to each scene. These formulas define, for example, possible preceding and subsequent scenes.

THE THEORETICAL ASPECTS OF CONSENSUS-BASED TUTORING STRATEGY STARTESELECTION

The structure of strategies includes the following:

- K: set of knowledge pieces, $K=(\text{Pre-condition, Post-condition, Contain})$
where:
+ Pre-condition is a set of logic formulas to be fulfilled by candidates, which are needed for understanding the knowledge in Contain
+ Post-condition is a set of logic formulas to be fulfilled by candidates,
+ Contain is a piece of knowledge.
- T: set of tests.

For a strategy, a sequence is generated that belongs to the Cartesian product $(K \cup T)^n$ for n being a natural number. Let *Str* also be the set of strategies.

It is possible to calculate the similarity function between strategies, although the following constraints should be considered:

- The similarity of knowledge pieces (scenes) appearing in strategies.
- The order of knowledge pieces.
- The contents and order of tests.

The similarity function between strategies is called $d_1: \text{Str} \times \text{Str} \rightarrow \mathbb{R}^+$, where \mathbb{R}^+ is the set of non-negative real numbers.

The database of students (STUD) is a set of tuples (Begin_Grade, St, End_Grade), where:

- Begin_Grade:
- St: a sequence of strategies from set Str
- End_Grade:

The similarity of objects belonging to STUD is defined by function $d_2: \text{STUD} \times \text{STUD} \rightarrow \mathbb{R}^+$. The similarity between two students should contain the following information:

- The similarity between Begin_grades.
- The similarity between End_grades.
- The similarity between two sequences St of strategies; if these sequences have the same length, then their similarity should be equal to the sum of similarities d_1 between strategies on the same position.

The procedure for consensus choice is as follows. Let S be a given student who is characterised by three parameters:

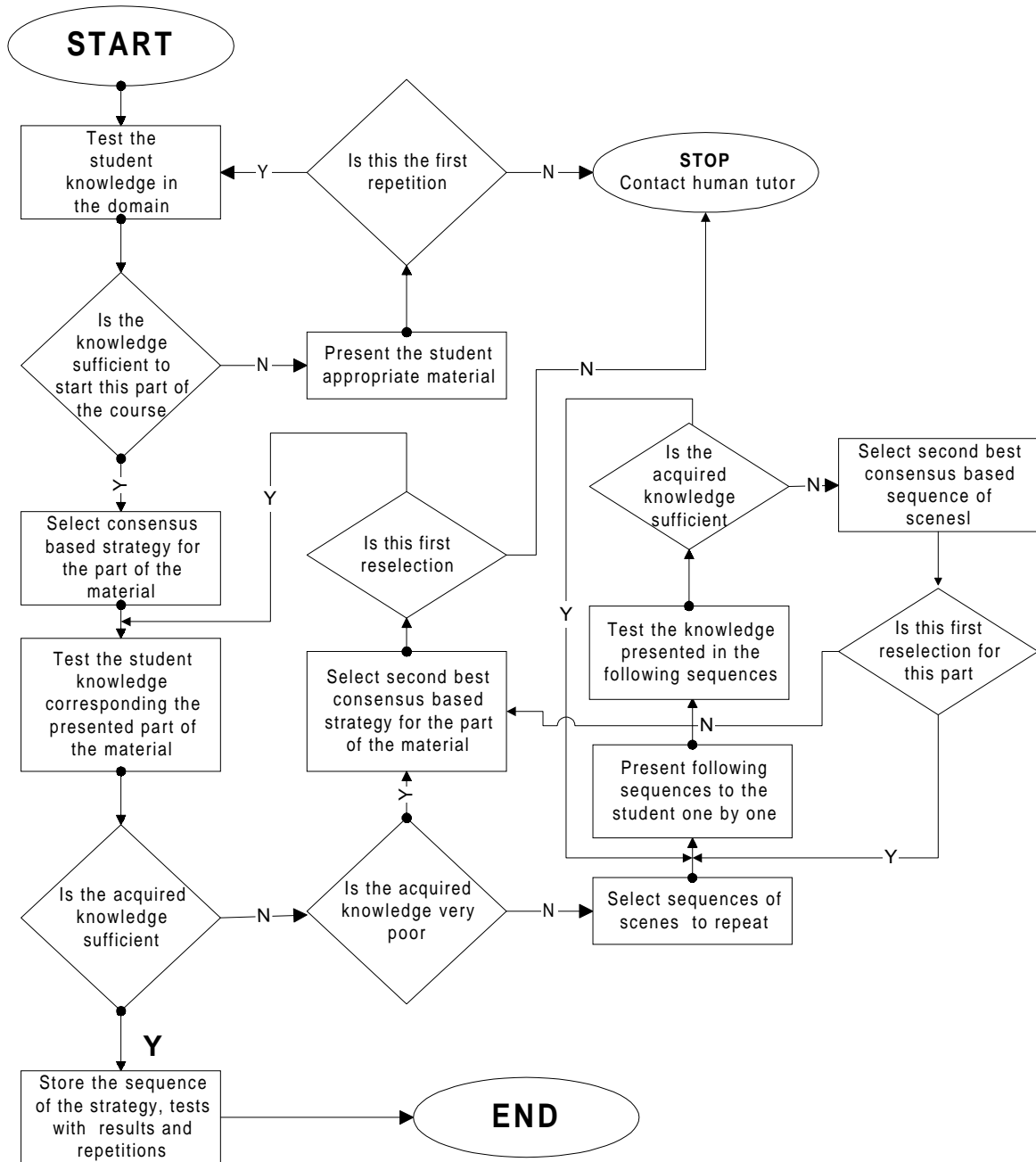


Figure 1. Algorithm for tutoring strategy selection.

- Begin_GradeS
- StS: a sequence of N strategies
- End_GradeS

A strategy from Str should be found that should be the best for student S. The procedure for determining the (N+1)-th strategy that should be the best one for given student S, is as follows. First, there should be the creation of a set $STUD_S$ from set $STUD$, which consists of such tuples (Begin_Grade, St, End_Grade), where St is restricted to N strategies that correspond to St_s , for which $d_2(St_s, St) \leq \epsilon$ (where ϵ is some threshold). Then on the basis of set $STUD_S$ create set $STUD'_S$ where $STUD'_S = \{(N+1)\text{-th strategy of sequence } St \text{ where } St \in STUD_S\}$. After this, such strategy St^* should be determined from Str as the consensus for set $STUD'_S$, such that:

$$\sum_{s' \in STUD'_S} d_1(St^*, s') = \min_{s \in Str} \sum_{s' \in STUD'_S} d_1(s, s')$$

Then St^* should be taken as the (N+1)-th strategy for the student S.

EXAMPLES OF DIFFERENT TUTORING STRATEGIES

The following examples refer to the tutoring of principle laws in dynamics. It is only a fragment (limited to the second law of dynamics) of a more complex example presented elsewhere [7]. Suppose that the multimedia tutoring system contains three different tutoring strategies, each of them represented by a sequence of scenes. Each scene in turn is connected with a certain conception and represents its specific aspect. It is important that the contents of scenes are complementary so that when one strategy fails, it can be exchanged with another that presents the same conception in a different manner. The descriptions of succeeding scenes refer to their contents. In fact, each scene could be realised by different media of presentation (such as text, graphics, animation, video and sound) that is appropriate to the nature of taught conception.

Strategy 1

- *Scene 1: Introduction.* First law of dynamics defines the behaviour of a body when there is no unbalanced force

affecting it. The second law is complementary and defines what happens when there is such a force.

- *Scene 2: Second law of dynamics.* In an inertial system, there are some unbalanced forces that act on a body; it moves in accelerated motion and its acceleration is directly proportional to the force and inversely proportional to the body mass. The direction and turn of the acceleration is the same as direction and turn of resultant force. This law is often presented in the form of equation:

$$\vec{a} = \frac{\vec{F}}{m},$$

where: a = acceleration, F = resultant force affecting the body, and m = body mass.

- *Scene 3: Illustration of the second law of dynamics.* In considering the motion of a body falling down from a high tower, it can be noticed that as the body approaches the ground its speed increases. The only forces affecting the body are its weight and resistance of the air. The result is an unbalanced force that, according to the second law of dynamics, causes the accelerated motion of the body in a vertical direction to the Earth's surface. The acceleration in this case is nearly equal to gravity.

Scene 4: Example of practical use of the second law of dynamics. Here is an example of a problem: During the first 10 seconds from the beginning of uniformly accelerated motion, a body has attained velocity equal to 5 m/s. What are the resultant forces affecting it, if the body mass amounts to 2 kg and the friction force is equals 4 N? The solution involves first calculating the acceleration of the body using the formula: $a=v/t$, because its initial velocity is equal to zero. Next, the resultant force should be ascertained. According to the second law of dynamics this force should balance the friction force and cause the acceleration of the body motion:

$$F = T + m * a.$$

In substituting the names of variables with their values, the magnitude of the resultant force can be calculated;

$$F = 4N + 2kg * \frac{5m/s}{10s} = 5N.$$

Scene 5: Generalised second law of dynamics. If the definition of the acceleration known from kinetics is compared:

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$$

then the second law of dynamics can be formulated in a different manner. The increase of the body impetus is equal to the product of the force affecting it and the time in which this force acts:

$$\Delta\vec{p} = \vec{F}_{resultant} * \Delta t.$$

- *Scene 6: Illustration of the generalised second law of dynamics.* Consider a rocket that is moving in accelerated motion in consequence of a jet-propelled engine. As time progresses, the engine uses more fuel. Finally, the rocket's mass decreases. In this case, the change of velocity, as well as the change of mass, cause the impetus change.

Strategy 2

- *Scene 1: Introduction.* This could be the same scene as in Strategy 1.
- *Scene 2: Experience 1.* Description of the experience concerned with the second law of dynamics, including

generalised and *classic* forms of the second law of dynamics, as well as impetus conception.

- *Scene 3: Second law of dynamics.*
- *Scenes 4 and 5: Examples of using the second law of dynamics.* One simple example (as in Strategy 1) and one more complex example, including a situation when only the generalised second law of dynamics is fulfilled.

Strategy 3

This strategy involves the generalised and *classic* formulation of the second law of dynamics, the conception of impetus and simple descriptive examples of its use.

- *Scenes 1, 2 and 3: Second law of dynamics.*
- *Scenes 4, 5 and 6.* These scenes refer to the examples of using second law of dynamics. They should be complex and require wide knowledge in the scope of the previously introduced dynamics laws.

Unfortunately, there is no room to present some typical tests that students are obliged to solve after each part. Particular test questions refer to different aspects of tutoring material. Some will refer directly to the contents of pages while others demand more advanced knowledge and skills.

SUMMARY

This paper presented the general outlines of the consensus-based tutoring strategy selection in Computer-Assisted Learning (CAL) systems. This method has its origins in the authors' works on interactive systems design and interfaces [7]. The method has not been verified yet but it is hoped that, in the near future, a prototype will be constructed concerning the domain presented in the example and then apply it to DL environments in multimedia information systems and domains of logic [8].

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