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Experience applying language processing techniques to develop educational software that allow active learning methodologies by advising students

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ABSTRACT

This paper is focused on those systems that allow students to build their own knowledge by providing them with feedback regarding their actions while performing a problem based learning activity or while making changes to problem statements, so that a higher order thinking skill can be achieved. This feedback is the consequence of an automatic assessment. Particularly, we propose a method that makes use of Language Processor techniques for developing these kinds of systems. This method could be applied in subjects in which problem statements and solutions can be formalized by mean of a formal language and the problems can be solved in an algorithmic way.

The method has been used to develop a number of tools that are partially described in this paper. Thus, we show that our approach is applicable in addressing the development of the aforementioned systems. One of these tools (a virtual laboratory for language processing) has been in use for several years in order to support home assignments. The data collected for these years are presented and analyzed in this paper. The results of the analysis confirm that this tool is effective in facilitating the achievement of learning outcomes.

1. Introduction

One of the main learning objectives of any teaching methodology is to allow students to achieve higher order thinking skills (Bloom, 1956; Anderson and Krathwohl, 2001) while they acquire knowledge and develop corresponding intellectual capabilities. To achieve this objective, teachers, lecturers and professors can use several teaching–learning methodologies (Oser and Baeriswyl, 2001). Education in the fields of Science and Engineering usually incorporate learner-centered education (Norman and Spohrer, 1996). The most widespread teaching–learning methodology usually merges theoretical lectures and practical laboratory sessions (or virtual laboratory sessions) in order to provide students an active learning environment (Bonwell and Eison, 1991; McConnell, 1996), by applying a Problem Based Learning (PBL) approach (Dewey, 1922). Some researches have pointed out that this approach facilitates more effective and improved learning, whereby students are involved in learning activities that require problem solving (Eden et al., 1996; Makonnen, 2000). Home assignments are usual tasks to involve students in problem based activities. However, it has not been possible to give individual feedback given the current resources (Salmela and Tarhio, 2004).

Because Information Technologies can help to achieve the above-mentioned higher order thinking skills (Churches, 2008), students can benefit from the use of Computer Aided Learning (CAL) environments. Our research will focus particularly on those systems that aid students in building their own knowledge by providing feedback regarding the consequences of their actions while engaged in a learning activity. In these systems, feedback is the foundation for the building of knowledge (Gordijn and Nijhof, 2002), as students can modify and improve the solutions they propose (Bravo et al., 2009). In this regard, the studies of Kumar (2004) suggest that systems which provide any kind of feedback to students are more effective than those that do not, and they can be used as a supplement to classroom instruction (Fernandes and Kumar, 2005). In addition, Sanders and Hartman (1987) noticed that when learners observed the assessment of their assignments, it helped them to justify their choices when solving a problem by evaluating the advantages and disadvantages of each possible choice.

Furthermore, feedback regarding a student's assignments is not only useful for that student, but also for the system, so that it can guide the student's learning process. This is the case with Intelligent Tutoring Systems (ITS) (Murray, 1999, 2003) and Adaptive Hypermedia Systems (AHS) (Brusilovsky and Peylo, 2003), where the

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system sets the learning-activity flow as a consequence of the assessment of what students deliver on specific assignments. Therefore, in systems of this kind, feedback can be used: (1) to assess the degree in which the objectives are being achieved in the learning process; (2) to determine whether there is a need for replanning the learning activities; (3) to adapt the learning process to a student's specific cognitive characteristics (Jurado et al., 2008).

In addition, to allow students to test more alternatives, we hypothesize that they must be able to introduce their own changes to the statement of the problem, so that higher order thinking skills can be achieved. Thus, taking Bloom's Taxonomy (Bloom, 1956) into consideration, in which the thinking skills order is categorized as: knowledge; comprehension; application; analysis; synthesis; and evaluation; and allowing students to test as many alternatives as they wish, and even to introduce their own proposals of assignment in order to validate them, we could state that they are working in the higher order thinking skills: (1) in the application level, because they are able to use their knowledge to solve an assignment; (2) in the analysis and synthesis levels, due to the fact that they are able to create new assignment statements; (3) in the evaluation level, because they are be able to corroborate the accuracy of their evaluation for a specific solution.

Therefore, the aim of our research has been to identify a formal technique that facilitates the building of systems which allow students to specify problem statements, to introduce alternatives solutions to problems and to analyze the corresponding evaluation by mean automatic assessment. This evaluation will provide the corresponding feedback to students and, consequently, they will be able to identify possible mistakes in both the formalization of the problem and the solution.

Thus, in this paper, we will present an approach that makes use of Language Processor techniques for designing and developing educational software tools that allow students to formalise problem statements, to express possible solutions and to evaluate them. These tools could be applied in those subjects where the problem statement and the solution can be formalised through a formal language, and where the problem can be solved by means of a tractable algorithm to efficiently compute the solution to the problem. In the designed formal languages, their semantic will be syntax-driven. Therefore, the semantic analysis will be carried out directly into the parsing process.

In order to have the corresponding application frameworks to test our approach, we have selected three different engineering courses: Formal Languages and Automata Theory, Language Processors, and Electronic Circuits. Therefore, we have enough scenarios to make a preliminary test of the versatility of our proposal. In this way, as example to clarify our explanation, we will expose our approach by showing the developed tools for the above-mentioned courses.

This paper is organized as follows: first, an overview of related works is presented; second, our approach is described; followed by an example of application of the techniques, which will show how our approach is applied; subsequently the experimental results of the last six academic years are discussed; and finally, some conclusions are drawn.

2. Overview and related works

There are several approaches in addressing the problem of analysing the solutions to assignments provided by students in several specific learning domains. Thus, COALA (Jurado et al., 2009, 2012), uses fuzzy logic to assess programming assignments by comparing the tutor's ideal solution with that delivered by the students, taking into account the imprecision while implementing it. Also, ViLLE Tool (Rajala et al., 2008) includes techniques and mechanisms to provide automatic assessment and feedback. However, these tools are not used in user-defined domain courses. A good survey about techniques used in this kind of system can be found in (Ala-Mutka, 2005; Rahman and Nordin, 2007). They are only applied to programming learning courses.

Co-Lab (Bravo et al., 2009) analyses similarities of objects, and the relationships between students' solutions and the ideal solution in a modeling process for System Dynamics. DomoSim-TPC (Bravo et al., 2006) uses a meta-description for Domotics Designs in terms of types of objects, relationships between them, rules for model building, behavior of component model, etc. so that the students solutions meta-description is compared to the ideal meta-description. KERMIT (Suraweera and Mitrovic, 2002) assesses students solutions by using a knowledge base that consists of a set of constraints for conceptual database design. In He et al. (2009), we see an approach that makes a semantic assessment of summaries written by students, by merging Information Extraction and Natural Language Processing.

The main restriction in each of these approaches is that all are dependent on the inclusion of a database with predefined problems and their ideal solutions as specified by experts. These systems must then match the solution delivered by the student with the ideal solution for a specific problem. Each approach implements its specific matching technique in order to detect the differences and similarities between solutions in order to advise students of what they are doing well, and what they are doing wrong. This situation restricts each approach to specific domains, and limits them to a set of problem assignments.

ACE is a system for automatically assessing assignments related to finite state automata and parsers (Salmela and Tarhio, 2004). This system includes a client to perform assignments as well as verifiers to check them. However, ACE is applied only to a specific domain. In addition, with ACE the assignments can not be defined by students.

So far, we can see that there is no one approach that can be used for several domains. Moreover, none of these approaches allow students to specify new assignment specifications by themselves, apart from the system's predefined assignments. Thus, in the next section we will present an approach that allows the specification of both the problem and the solution, by using Language Processing techniques. With this approach, students will be able to propose their own problems, as well as possible solutions to those problems, while the system gives advice regarding how the proposed solution fits the proposed problem.

3. What is the proposed approach?

In this section, we present our proposed technique for designing and developing educational software tools that allow students to specify problem statements, to introduce alternatives solutions to those problems, and to receive evaluation results from the system. This feedback is essential for students to assess how they are progressing, and it could be used by the tool to guide students through the learning process. Moreover, the tool could also be used by teachers as a classroom aid in order to present and illustrate lessons, to receive immediate feedback in lectures, and to allow examples to be modified accordingly so that it will help students understand them better. This promotes a new method of working in class which breaks with the classical pattern of classroom activity based mainly on one-way knowledge transmission/reception of pre-elaborated concepts.

In the next subsection, we will explain the suggested technique in detail; next we will present the architecture of the designed