

A Learning Companion System for Distance Education in Computer Science

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Abstract. *In this paper we present LeCo-EAD - a Learning Companion System for distance education in computer science. LeCo-EAD includes multiple virtual learning companions that have different behaviours and are always available to interact with distant students. We show how a web-based distance course that adapts both its navigation support (links) and strategy (type of learning companion) to the student, can contribute to improve students' motivation, reflection, and self-assessment skills. We report on the results of an experiment carried out with students and teachers of an undergraduate course on Object Oriented Programming in Java.*

1. Introduction

Distance learning is gaining space as an alternative modality of education in several areas, including among them, Computer Science. This paper presents LeCo-EAD [Faraco et al 2004], a web-based distance education system that uses the approach of virtual learning companions and software agents. LeCo-EAD is a tool that includes multiples agents, is highly available to the distant student, and is able to adapt to the student profile.

The development of LeCo-EAD followed the approach of a formative evaluation. Accordingly, it was used by teachers and students of a Computer Science undergraduate course on Object Oriented Programming in Java. After interacting with the system, teachers and students were submitted to interviews. The results of these interviews served both as a basis to inform the system design and as a partial evaluation during the prototype development process.

The paper is organized as follows. In Section 2, we outline intelligent distance education. In Section 3, we introduce Learning Companion Systems, first describing distance education with learning companions and then detailing the LeCo-EAD architecture. In Section 4, we report on the results of an experiment carried out with LeCo-EAD in an undergraduate course on Object Oriented Programming in Java. In Section 5, we present our conclusions and directions for further work

2. Intelligent Distance Education

Distance Education is a modality of education that has as main characteristics the physical separation between teacher and student, and the communication between them made through some kind of media. According to Bates [Bates 1995], media is a generic form of communication associated with a particular way to represent knowledge. Amongst the media used to support the interaction between teacher and student in distance courses, we may cite: printed materials, audio, video, teleconferencing, videoconferencing, Internet, and software.

The evolution of distance learning took place during the last two centuries according to the media that was available for interaction between teacher and student. This characterized the distance learning generations. From postal mail (1st generation) to the use of web-based virtual environments (4th generation), the search for enriching the process of teaching and learning at a distance through the new information and communication technologies seems to converge to the 5th generation of distance education. In the 5th generation, without human interference it is possible to experience the most advanced form of distance education: the students interacting through connected computers, accessing the courses contents, and also having the possibility to discuss and collaborate with other students [Taylor 2001].

In this context, there is an increasing interest in the development of computational systems that improve this form of education, such as the combination of web-based distance learning and Intelligent Tutoring Systems (ITS). As a result of interaction with the students, such systems perceive (among others) their characteristics, pace of learning, and learning style, and can adapt the didactic materials presentation, pedagogical strategies, feedback messages, and so on.

In the area of Artificial Intelligence in Education we can notice the development and testing of various web-based ITS [Frasson et al 1998, Nakabayashi et al 1997, Stankov et al 2000, Woolf et al 1997]. The advantage of individualized instruction in such systems is particularly interesting because it allegedly promotes a more efficient teaching and learning process. In addition, ITS can provide real-time support to the distance learning process [Rosatelli et al 2000]. However, the use of web-based ITS did not overcome the characteristic problem of students' isolation in distance courses.

At the same time, the evolution of computer networks and distributed systems contributed for the growth of collaborative learning systems. The main benefit of these systems is the creation of virtual networks of learning. Therefore, they contributed to diminish the students' isolation problem. On the other hand, they do not guarantee the availability for interaction of remotely distributed students.

Learning Companion Systems (LCS) [Chan and Baskin 1990, Chou et al 2003] can be considered an alternative solution to the students' isolation problem in distance courses, since the virtual learning companion are always available to interact with students. The use of software agents, through its properties of autonomy and communicability, creates the conditions to provide the learning companion with desired functional characteristics in the context of distance learning.

An interesting characteristic of LeCo-EAD, besides being a web-based virtual learning system that adapts to the user, is providing the possibility of interaction

between the students according to the pedagogical approach of collaborative learning. According to Vygotsky's socio-cultural philosophy [Vygotsky 1978], learning results from a process of interaction with other eventually more capable subjects, forming a community of learning.

3. Learning Companion Systems

LCS were initially proposed by Chan and Baskin [Chan and Baskin 1990], and are considered an evolution of ITS, in which the system architecture includes an additional component, the Learning Companion (LC). The role of a LC is to be a virtual peer for the human student, interacting with him or her in order to collaborate with the learning process similarly as the interaction with another (real) student takes place.

LCS make use of the pedagogical approach proposed by Vygotsky. According to this approach, the construction of knowledge implies in a shared action, i.e., through the interaction with similar and eventually more capable peers, the relation between subject and object of knowledge is established. The different paces, behaviours, values, experiences, and knowledge levels allow the cooperation and the competition, which are important elements in expanding the individual capacities [Vygotsky 1978].

3.1. Distance Education with Virtual Learning Companions

The great advantage presented by LCS - that provide a virtual and eventually more apt peer (rather than a real one) as part of its architecture - in distance learning, is the LC total availability to the human students, stimulating the latter to interact with the system and learn collaboratively [Goodman et al 1998].

The use of LCS in distance education gathers the advantages of the ITS individualized education approach and collaborative learning by social interactions of Computer Supported Collaborative Learning systems. Individualized education happens when the system makes available to the student only the concepts that he or she is able to handle, according to his or her performance in the course. Also, the LC presents feedback messages that are related to the student individual behaviour. In addition, the advantage of social-cultural learning can be observed by the presence of the LCs, which are always available to interact with the students that are remotely distributed. LeCo-EAD appears as an alternative that brings contributions to the consolidation of the so-called 5th generation of distance learning, which is characterized by adopting a model of flexible and intelligent education.

3.2. LeCo-EAD Architecture

LeCo-EAD can be visualized at a macro level as being composed by the classic modules of ITS architecture (namely the domain module, the tutor model, the student model, and the graphical user interface) with the addition of the Learning Companion Agents (LCAs). Besides, its architecture is based on the concept of software agents. Figure 1 presents LeCo-EAD architecture, highlighting the system modular aspect.

Domain Module

The domain module includes the knowledge about the subject matter. It comprises the contents to be presented to the student through the web pages, which are organized in LeCo-EAD as conceptual maps. The objective of a conceptual map is to contextualize the subject attributing meaning to the topics studied [Novak 1977, Cañas et al 1995]. The concepts included in the map are studied one by one. At the end of each concept a set of exercises is presented to the student aiming to evaluate him or her. Depending on the student performance, other concepts of the map are liberated according to a prerequisites structure. A degree of importance (given by a percentage) is attributed to each concept in the structure defined through the conceptual map. The exercises also possess related weights that represent their degree of importance for mastering a particular concept. Figure 2 shows an example of a conceptual map on Object Oriented Programming in Java.

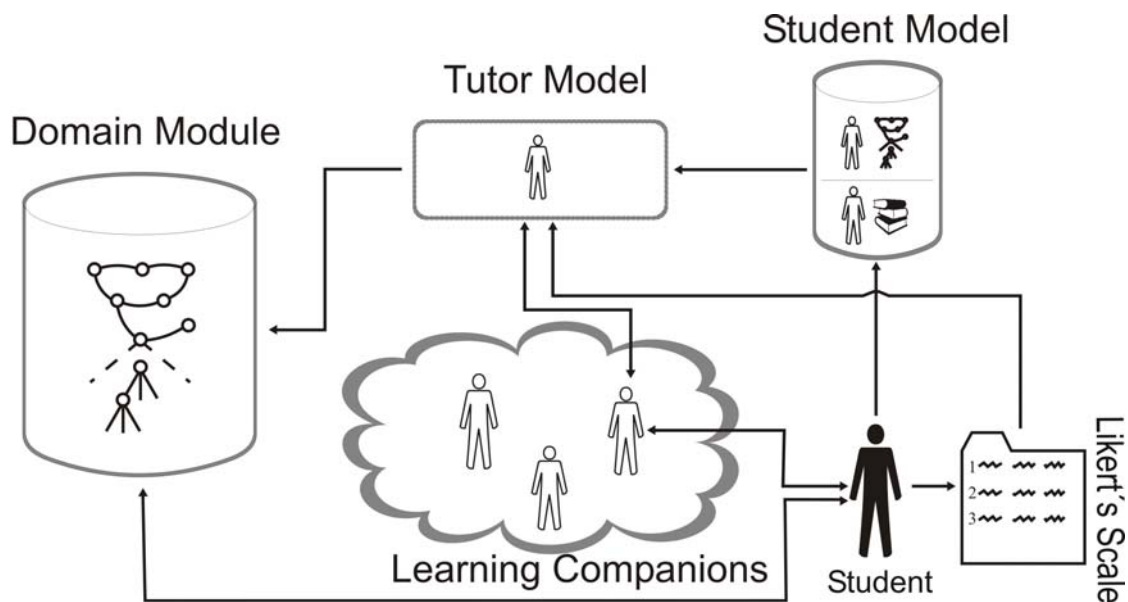


Figure 1. LeCo-EAD Architecture

Student Model

The student model represents the student knowledge about the subject matter during his or her interaction with the system. For each concept included in the conceptual map, the system represents both if the student knows or does not know the subject matter and a quantitative measure of how much he or she knows about it. Each student model includes information about the student performance in solving the exercises of each unit of the contents, the tracing of the student access to the system, and the kind of LCAG used. The knowledge management agent, which manages the student model, updates the value accumulated by the student during the exercises solution. The updating of the weights in the contents structure is based on the certainty factor model initially proposed for handling uncertainty in [Buchanan and Shortliffe 1984, Durkin 1994].

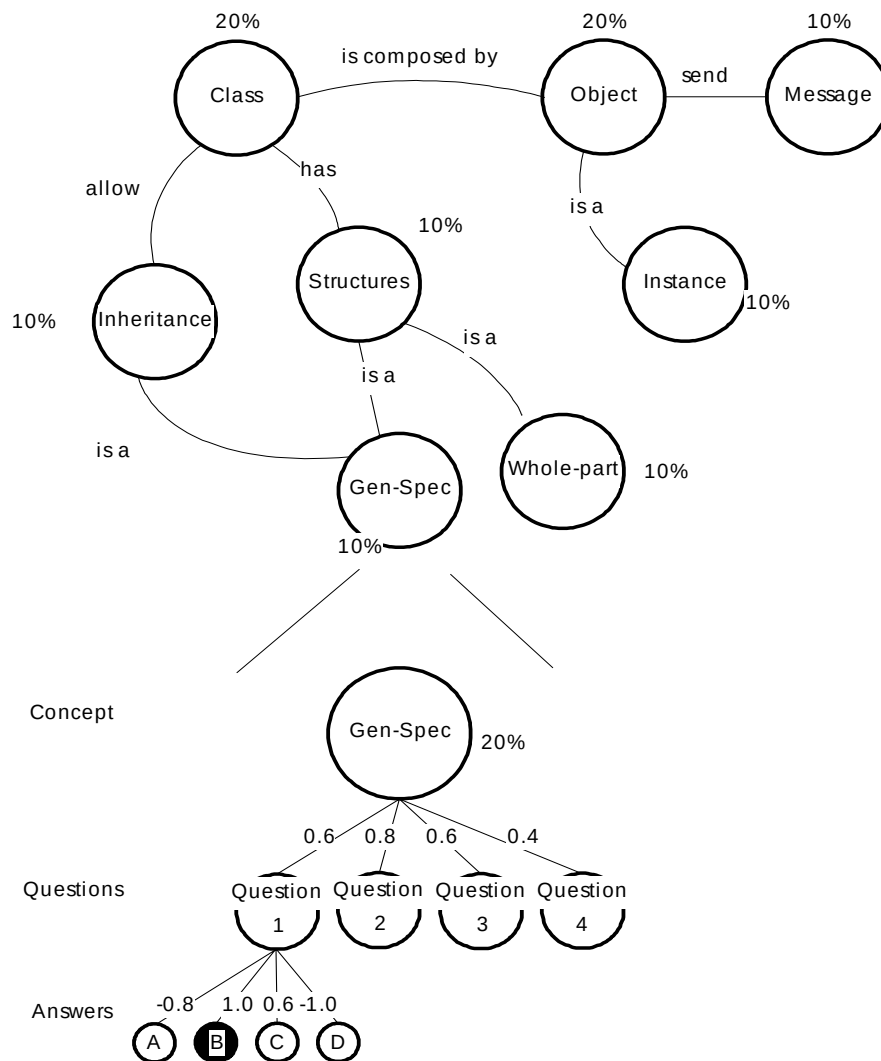


Figure 2. A Conceptual Map on Object Oriented Programming in Java.

Tutor Model

The tutor model, through the coordinating agent, makes the selection and sequencing of the subject matter to be presented. The issues that are relevant to this task are: when to revise, and when and how to provide additional information. That is, this model deals with the pedagogical knowledge, and is the basis of the pedagogical decisions, which are made in accordance to the individual needs of each student. LeCo-EAD coordinating agent, based on the prerequisites of the discipline contents, manages the contents sequencing, deciding what and when presenting a certain topic to the student, and liberating the concepts represented in the conceptual map as the students reaches a satisfactory score to progress from one level to the next one. Moreover, this agent is responsible for choosing and activating the LCAGs during the solution exercises by the students, and acts based on two specific events: the time and the kind of response given to each exercise.

Likert Scale

In LeCo-EAD the student actively participates in the process of choosing his or her LCAG. In order to accomplish this, an instrument that indicates the predisposition of the students in relation to objects, people, or events was used. In our particular case, a Likert scale [Likert 1932] that identifies which pedagogical strategy of the different kinds of LCAGs is appropriate to a particular student profile was elaborated. The Likert scale was implemented as an electronic form (like a questionnaire) that must be filled out by the student in the first time that he or she interacts with LeCo-EAD. The choice of the items (questions) to elaborate the Likert scale was based on a study of the different learning styles that can be assumed by the LCAGs [Nichols 1994, Chan 1996, Chan 1995]. At first, the scale elaborated was composed of 27 items (questions) and, after a qualitative analysis, the number of items (questions) was reduced to 25.

In order to make the Likert scale reliable, we collected a pre-test sample using as target-public 92 students of the last semesters of Computer Science and Information Systems undergraduate courses. After collection and tabulation, the data was submitted to a statistical analysis, with emphasis in the Cronbah's alpha reliability coefficient [Santos 1999] and factorial analysis of the items.

Learning Companion Agents

LCAGs are virtual students that interact with the user (student) in different ways: guiding, learning, and/or provoking the student. The application of the Likert scale provides a reasonable approximation to the profile that the student prefers for his or her LCAG type. Three types of LCAGs were implemented in LeCo-EAD: collaborator, learner, and trouble maker. Each agent has a set of messages according to their type, which are sent to the student in two situations: (1) when the student is in doubt, what is identified by the system when the time of response to the exercise exceed a pre-established limit; and (2) through the kind of response given by the student. Besides the messages, each agent has a graphical personification related with its type.

4. Teaching Object Oriented Programming in Java Using LeCo-EAD

LeCo-EAD was implemented in the domain of Object Oriented Programming in Java. Teaching object oriented programming using this tool is particularly interesting because the discipline typically involves an initial theoretical part followed by practical problems that must be solved by the students. The system is a valuable resource to both parts. It is worth noticing that this virtual learning system is domain independent, and can be used to support distance courses on any subject matter.

In addition, in LeCo-EAD any user can play the role of an instructional designer, creating a course without the necessity of knowledge in programming for the web. Rather, the user (e.g., the instructional designer) should only provide the following information: the course contents organized in concepts, the prerequisites between them, a set of exercises, a list of students, the teacher's name, and the agents' configuration.

During LeCo-EAD development, we adopted a formative approach, along the same line as [Tedesco 2001] and [Meizalo et al 2002]. The LeCo-EAD prototype was initially tested by a group of teachers and students of the Computer Science and Information Systems that were enrolled in the courses of Object Oriented Programming

in Java. Thus, 5 teachers and 20 students participated of the system evaluation, which consisted of three stages. In the first one, there was the presentation of the prototype followed by a session of interaction with the system, guided by the experimenter. Next, the teachers worked on the course design and afterwards the students followed the course, studying the contents provided by the teachers. Finally, the participants were interviewed. The interview focused on aspects such as usability, flexibility, functionality, and system availability.

4.1. Experimental Results – Teachers

Course authoring: the subjects' answers to the questions posed showed that the possibility of authoring the course contents, defining the prerequisites, structuring the conceptual maps, configuring the LCAGs, among others, brought a great flexibility to the environment according to the teachers' point of view. The author (teacher) can create courses in any knowledge domain and configure the LCAGs with freedom and creativity, and without the need to have a background on web-based systems development. Opposed to the domain independence and flexibility is usability, i.e., the more generic, the greater the number of parameters that are needed for the software configuration. In this sense, it was suggested that the teacher module in LeCo-EAD – that is where all the configurations and parameters of the courses are set – provides an intuitive and easy to use graphical user interface. The need for training the teachers in structuring the course contents through related concepts in the conceptual map was also mentioned.

Graphical user interface: the biggest number of suggestions from the subjects for improvements in LeCo-EAD concerned the graphical user interface. A greater usability for the system regarding the course design, the configuration of the messages of LCAGs, the registration of the contents and respective weights, and the agents' animation feature, were the main issues raised during the interview sessions.

4.2. Experimental Results – Students

Using LCS in distance learning: as stated above (cf. section 2), using LCS in distance education seeks to gather the advantages of individualized education and high availability of LCAGs. The users that were interviewed were unanimous in considering the functionality related with this issue in LeCo-EAD very positive. According to them, the fact that the system monitors the student during the course, and according to his or her profile adapts to the student, gives them a greater sense of confidence. The LCAGs availability was mentioned as another important benefit in a distance course. This result is in accordance with the Vygotsky social-cultural learning approach [Vygotsky 1978], and there is a strong indication that the role of LCs can contribute particularly to student's motivation, reflection, and self-assessment skills during the learning process.

Adaptation in LeCo-EAD: LeCo-EAD adapts the course characteristics to the student at two different moments: first, when the system makes a decision about the type of LCAG that is appropriate to a certain student; second, when updating the conceptual map. The students that were interviewed stated that the property of adaptation is a distinguished feature of LeCo-EAD in relation to web-based distance learning systems in general. The LCAGs with the appropriate profile cooperate with the student during the solution of the exercises. The conceptual map allows that the student have a macro

vision of the course contents and can keep track of what he or she should or should not study, depending on his or her performance. The fact that the student has to follow a pre-requisites structure – in which he or she needs to reach a certain score regarding a certain concept, so that the next ones are liberated to appear in the map – regulates the process of student interaction with the course materials

Mechanism for choosing the Learning Companion Agent: the mechanism that LeCo-EAD uses to make the choice of which type of LCAGs will be activated to cooperate with a particular student was considered clear and direct. The user participation in this process is explicit, either through the Likert scale or the feedback mechanism. The student fills out the electronic form (i.e., the Likert scale) scale once in the beginning of the course, and later on he or she controls the acceptance of the LCAGs by closing the messages window. The conceptual map adaptation, which is made based on the student performance during the exercises solution, was well accepted by the subjects.

5. Conclusion and Further Work

The paper presented LeCo-EAD - a learning companion system for distance education in Computer Science. LeCo-EAD is composed for multiple learning companion agents that adopt different pedagogical strategies and are always available to interact with the students via the web.

Under the approach of a formative evaluation, experiments with LeCo-EAD were carried out in a course on Object Oriented Programming in Java. The subjects reported on the system positive and negative aspects by answering a questionnaire and responding to an interview. Amongst the positive aspects, they mentioned the reduction of the student isolation, individualized instruction, independence of domain, and improvement on the students' motivation, reflection, and self-assessment skills.

The issues that were raised by the subjects, which will serve as directions for future work, are the need for improving the graphical user interface and the activation of LCAGs during the whole course as opposed to only during the solution of exercises.

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