Intelligent and Adaptive User Interfaces for Ubiquitous Learning

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Abstract. Advances in mobile computing and in communications networks have allowed the possibility of u-learning (ubiquitous learning), which is the union of two educational systems: adaptive e-learning (electronic learning) and m-learning (mobile learning). One way of implementing a u-learning platform is utilizing an intelligent and adaptive user interface that adapts itself as the student's knowledge evolves, while helping him/her with tasks like intelligent searches and recommendations of learning material. The implementation of these user interfaces raise problems, like building a model of the student, which we propose can be solved using Bayesian networks. The purpose of this paper is twofold. First, to present our research in this area. Second, to report our first steps in constructing a u-learning platform for learning statistics.

Key words: Adaptive User Interfaces, Intelligent User Interfaces, Ubiquitous Learning, Mobile Learning, E-learning, Bayesian Networks.

1 Introduction

U-learning (ubiquitous learning) is a learning system that allows a student to receive personalized instruction anywhere and anytime. Thus defined, u-learning can be seen as the union of two learning systems: adaptive e-learning (electronic learning) and m-learning (mobile learning). Adaptive e-learning allows students to receive personalized instruction on a desktop computer by means of Internet, an intranet, a CD-ROM, or any other tool. On the other hand, m-learning (mobile learning) allows students to receive instruction anywhere and anytime on a portable computer by means of communication technologies like Wi-Fi or GSM.

A platform for u-learning can be implemented by means of an adaptive user interface that adapts itself to the students level of knowledge, computer skills, preferences, and to the features of the computer being utilized in the learning process. Furthermore, the interface should also be intelligent in order to help students by performing tasks like generating an appropriate study plan, giving recommendations of relevant material, doing intelligent searches, and offering personalized help.

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The use of adaptive and intelligent user interfaces in a u-learning environment affects positively the students learning, by allowing them to study in a personalized environment at any hour, in any place, and from any computer. This way, students can center in the study of the subject, without having to lose time seeking for relevant material, or to depend on their computer skills in order to use the interface.

The aim of this paper is, first, to present our research on the main challenges of implementing an adaptive and intelligent user interface, and second, to report our first steps in implementing a u-learning environment for learning statistics. To this end, the rest of this work is organized as follows. Section 2 defines the basic concepts related to u-learning. Section 3 discusses the main problems that need to be solved to implement a platform of u-learning. Section 4 presents Statistics-to-Go, which is a project aimed to implement a m-learning platform for learning statistics. This is our first step toward the broader aim of implementing a u-learning platform. Finally, Section 5 presents our conclusions.

2 Basic Concepts of U-learning

This section defines the concepts of adaptive e-learning (Subsection 2.1), m-learning (Subsection 2.2), and u-learning (Subsection 2.3).

2.1 Adaptive E-learning

E-learning, also known as online learning, is defined as the instruction received by means of a CD-ROM, Internet, or intranet. E-learning can be synchronous or asynchronous [1, p. 10]. Synchronous e-learning is carried out in real time on a virtual classroom with an instructor. Thus, students and the instructor coincide in time though they are not necessarily at the same place. On the other hand, in asynchronous e-learning students and the instructor do not share the same time or place, and it is designed so students can learn at their own pace. Both formats allow the use of collaborative learning tools like wikis, discussion forums, and email.

Traditional e-learning offers the same service to all students without taking in account their previous knowledge, learning goals, communication skills, and preferences. Since the decade of 1970s, however, the impact of human differences on education were recognized [2]. That is, a "one-fits-all" education do not satisfy all students and then it is necessary to look for new teaching paradigms as, for example, adaptive e-learning.

Adaptive e-learning suggests a solution to this problem by adapting the instruction to the specific needs of each student. A more formal definition is that adaptive e-learning is an online teaching system that adapts selection and presentation of learning contents to the students in an individual way based on their previous knowledge, personal needs, learning style, and preferences [3, p. 24].

2.2 M-learning

M-learning is the acquisition of knowledge by means of some mobile device [4]. In this work, mobile device means cellular phones or personal digital assistants (PDAs).

The differences of m-learning with other types of learning, especially traditional e-learning, can be studied by considering both the technology involved and the educational experience. Regarding technology, m-learning differs by the use of portable equipment that allows students to access learning objects anytime and anywhere. Regarding the educational experience, Traxler [5] compares m-learning and e-learning using keywords. This way, m-learning is 'personal', 'spontaneous', 'opportunistic', 'informal', 'pervasive', 'private', 'context-aware', 'bite-sized', and 'portable', whereas e-learning is 'structured', 'media-rich', 'broadband', 'interactive', 'intelligent', and 'usable'. The same author notes that some of these distinctions can disappear as mobile technology advance, but properties as informality, mobility, and context will remain.

2.3 U-learning

U-learning is an adaptive e-learning system that allows students to learn anytime and anywhere in a personalized environment. In other words, u-learning is the combination of adaptive e-learning and m-learning. Following a similar formula found in [6–8] we define u-learning using the formula:

$$\text{u-learning} = \text{adaptive e-learning} + \text{m-learning} . \tag{1}$$

The benefits of u-learning are evident. It has the same ones that adaptive e-learning, that is, u-learning allows students to select their learning objectives and to apply their own learning style [3, 9, 10]. In addition, students can utilize any computer and study from any place in the world. The main disadvantage, for now, is the high cost of the mobile component and of the connection, particularly in cellular phones. Nevertheless, as technology advances it is predictable that prices will diminish.

3 Implementation of a U-learning Platform

This section describes the main problems that arise in implementing a u-learning platform (Subsection 3.1) and presents Bayesian networks, a mathematical tool, that can be used to solve these problems (Subsection 3.2).

3.1 Main Challenges

We have identified the main problems that need to be solved in order to implement a u-learning platform. Also, we have grouped these problems in two broad areas: infrastructure and software. In the infrastructure area it is necessary to

have a Web server and computers, both desktop and portable, with Internet access. In the software area, the design and implementation of an adaptative and intelligent user interface raises four principal problems: creation of the student model, generation of the interface content, adaptation of the interface content, and evaluation of the interface.

We think that infrastructure problems can be solved by means of financial resources. Here we notice some official initiatives which can make u-learning feasible. First, there are organisms, like the One-To-One Institute [11] and The Anytime Anywhere Learning Foundation [12], who facilitate computing equipment by promoting the "one to one" policy - one computer for each student. Second, there are governmental policies, like u-Japan [13] and u-Korea [14], aimed to facilitate Internet access to everyone. On the other hand, software problems need special attention since their solution involves aspects of computer science. For this motive, in this section we will detail the mentioned software problems.

The student model captures relevant information about the student, for example, previous knowledge level, learning goals, learning style, and available time for studying. The model must realize an initial evaluation of the student estimating his/her knowledge in the matter of study and his/her computer skills, and then evolve as the student's knowledge and skills change. Some problems that we identify in order the model can work in a suitable way are the following: 1) the model must learn rapidly to be useful from the first moment, 2) the model must work with incomplete, and possibly contradictory information, received from the student, and 3) the model must be able to evaluate the knowledge and skills of the student so it can evolve.

Content generation consists of producing a personalized user interface with the ability to realize intelligent tasks, like searches and recommendations, which redound in a more effective learning experience. The most important problems that it is necessary to solve are: 1) to establish a relevancy criterion to arrange the learning objects, 2) to generate a learning path depending on the student's learning goals and the available time for study, 3) to support a data base with the learning objects that the student has found relevant in order to recommend them to other students with similar goals, and 4) to discover and to recommend objects of learning that could be of interest for the student.

Content adaptation implies changing the user interface as the student's knowledge evolve and as the student move from one computer to another with, possibly, different capacities and screen size. To achieve these objectives it is necessary 1) to have a data base with the features, for example screen size, of every computational platform, and 2) to adapt the content to the capacities of the computer that is being used.

Finally, it is necessary to measure the performance of the user interface. This implies finding metrics to quantify the user satisfaction with the interface in order to compare among several design alternatives.

3.2 Bayesian Networks

One method of implementing an adaptive and intelligent user interface is utilizing *Bayesian networks*, which "are graphical structures for representing the probabilistic relationships among a large number of variables and doing probabilistic inference with those variables." [15] This graphical structure is a directed acyclic graph, one can never return to the same node by following a sequence of directed edges. The graph has one node for each random variable in the associated probability distribution. Directed edges establish relationships among nodes. If there is an edge from node A to node B, then A is the "parent" of B and B is the "child" of A. This genealogical relation is often extended to identify the "ancestors" and "descendants" of a node.

Edges in a Bayesian network express the probabilistic dependencies between variables in a way consistent with the Markov condition: any node in a Bayesian network is conditionally independent of its nondescendants, given its parents [16, 17]. As a consequence, any Bayesian network specifies a canonical factorization of a full joint probability distribution into the product of local conditional distributions, one for each variable given its parents. That is, for a set of variables X_1, X_2, $\cdots$, X_N, we can write:

$$P(X_1 = x_1, X_2 = x_2, \cdots, X_N = x_N) = \prod_{i=1}^{N} P(x_i | Pa(X_i)) \; . \tag{2}$$

where $Pa(X_i)$ is the set of parents of X_i.

Bayesian networks can often be given a causal interpretation, an edge going from node A to node B indicates that A is a direct cause of B. This interpretation makes Bayesian networks particularly appealing for modeling high-level cognition. Once established the cause-effect relationships, there exist algorithms to make inferences.

Bayesian networks are a popular tool in applications that need to represent causal relationships and to reason with uncertainty [15, p. 649]. In e-learning, Bayesian networks can be used to determine the type of personalization with the intention of presenting a plan that optimizes the student's learning process [3], to measure the knowledge of the student, as a part of the initial diagnostic [18], and to detect when the student has problems exploring the learning material in order to provide guidance to enhance this exploration [19].

4 Statistics-to-Go: Toward a U-learning Platform for Learning Statistics

As a first step toward implementing a u-learning platform, we decided to implement a m-learning platform. We chose statistics because that is the background of one of the authors. This section presents the *Statistics-to-Go* project, whose main objective is to devise tools for learning statistics in mobile devices. The section starts presenting some background information (Subsection 4.1) and

listing the main advantages of a m-learning platform (Subsection 4.2). Then, the project's objectives are presented (Subsection 4.3). Finally, the project's methodology is shown (Subsection 4.4).

4.1 Background

In the University of Sonora, students majoring in Mathematics, Physics, and Computer Science take a mandatory introductory course of statistics. The objective of the course is to teach students basic statistical tools and to familiarize them with statistical analysis using statistical software. These statistical tools run only in desktop or laptop computers, which implies students must be either in the computer laboratory or carrying their laptops.

On the other hand, taking in account that in 2009 there were almost 80 millions of cellular subscribers in Mexico [20] and that around the world 50% of cellular phones are Java-enabled [21], we want to know if cellular phones can be useful to solve statistics problems, helping students to learn statistics anytime and anywhere, and liberating them from carrying their laptops or of having to be in the computer laboratory.

This way, Statistics-to-Go project was proposed in February 2010 with the goal of producing tools for learning statistics in mobile devices using Java ME (micro edition). Java ME was selected because almost all mid- and high-range cellular phones are Java-enabled, and this means Java ME programs (called MIDlets) are portable across mobile operating systems.

4.2 Justification

The main advantages of a m-learning platform are:

- There are no time or place restrictions. Students can learn anytime and anywhere.
- It allows context-aware learning. Students can receive learning objects depending of their location.
- Students can communicate among them, or with the teacher, without physical contact.
- Teachers can design quizzes and give students instant feedback.
- Teachers can design learning objects with integrated video and audio.
- Video and pictures can be used as an alternative way of learning.

4.3 Objectives

General Objective

- To devise tools for learning statistics in mobile devices.

Specific Objectives

1. To research which kind of statistics tools are useful for students taking the introductory course of statistics at the University of Sonora.
2. To develop a prototype of these tools.
3. To deploy the tools to students taking the statistics course.
4. To evaluate the usability of the tools by the students.

4.4 Methodology

The Statistics-to-Go project is set to run from March 2010 to February 2011 and has the following activities:

1. To apply a survey to obtain the number of students at the University of Sonora who carry a Java-enabled cellular phone.
2. To apply a survey to former students and professors teaching the statistics course in order to know which statistics tools are convenient to develop in cellular phones.
3. To develop the tools.
4. To deploy the tools to students taking the statistics course.
5. To apply a survey to students taking the statistics course to know the usability of the tools and their impact in the students learning process.

5 Conclusions

U-learning benefits students because it allows them to study anytime and anywhere in a personalized way, independently of the computer used. In spite of these advantages, there are not many implementations of u-learning platforms for learning mathematics, much less for learning statistics. We also highlight the lack of suitable learning objects. We think this is due to the cost of the infrastructure needed. Nevertheless, it is predictable that the cost of technology gets affordable with time.

Our future work includes the implementation of a m-learning platform for learning statistics, the research of the application of Bayesian networks to the implementation of an adaptive and intelligent user interface in a u-learning platform, and the design of learning objects for statistics.

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