

An Adaptive Web-based Tutorial of Agrarian Economy

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Abstract. TEA was originally conceived as a Computer Aided Educational System for teaching Agrarian Economy. This system was composed by web pages of instructional contents and web pages of test questions. One of the main lacks of this system was that there is not any control over the navigation process of the students through the pages. This contributed to the disorientation of students during the instruction. Also, in test questions, students only could know if they had succeeded in it, but these questions did not give them any feedback about their global level of knowledge in the topics of the tutorial. In this paper, TEA system has been improved making it adaptive. This has been achieved by using two tools: SIGUE and SIETTE. SIGUE is a web-based tool that converts non-adaptive courses into adaptive, and SIETTE is a web-based evaluation tool using adaptive tests. The functionalities of both tools have been integrated into a homogeneous adaptive TEA.

1 Introduction

There are many educational systems on the World Wide Web (WWW) that allow students to learn notions about different subjects. One of the main disadvantages of these web-based systems is the disorientation during the navigation. In textbooks the order of the knowledge units is defined by the book's author, but in web courses this order is not so clear. Because of the freedom and the availability of multiple links in the same web page, users can navigate without following a predefined order in the pages of a course, and even in pages not related with the course. In these cases, it is necessary to have some control technique to guide the user during the study of a subject.

Also, in this kind of systems, there are not mechanisms to infer if students have assimilated the concepts studied in a page. Therefore, before to let students pass to learn new concepts, some mechanism of evaluation is required to assess the students' proficiency.

Adaptive tutoring system provide the possibility of modifying the sequencing or presentation of the course for each user, according to their knowledge or preferences. Generally, they are difficult to implement due to the high development cost.

Another characteristic of adaptive tutoring systems, is that they can evaluate the level of knowledge of a user in relation to a knowledge unit of a course. Also, this information can be used to recommend him which unit should be studied next.

TEA [1] (this stands for *Agrarian Economy Tutorial* in Spanish) was originally developed as a web-based multimedia instructor system of Agrarian Economy. This system contains a set of static web pages structured into chapters. Each chapter is also divided into sections. At the end of each chapter, a set of questions is proposed to the students in order to evaluate their proficiency.

The static web site of TEA can be accessed in <http://www.lcc.uma.es/TEA>.

The main goal of this paper is to make the static instructor system of the TEA course, adaptive. Two different tools have been used to this end: SIGUE, that allows teachers to build adaptive courses from the static ones; and SIETTE, which is a web-based system for the evaluation by using adaptive tests.

In the next section, the SIGUE system and the procedure followed to make TEA adaptive using it, are described. In Section 3 a brief description of the main features of SIETTE, as well as the adaptive mechanisms which it uses, are treated. This section ends with a description of TEA test in SIETTE. Section 4 explains how the integration of both systems has been accomplished. At last, contributions obtained from this work are approached.

2 Creating contents with SIGUE

SIGUE is an author tool on the Web that can convert courses that weren't adaptive into adaptive ones. Also it's possible to create new courses from existing pages from different sources. This lets authors make courses with the best information on the Web about a subject. For each concept of the course the author can choose how many URLs can be associated with this concept, indicating the kind of content (theory, examples or exercises) and the importance of this URL to the concept.

SIGUE provides a student's interface that assists the students with adaptive tools when they navigate through the web pages. There are some hints in this interface to help the student. The different concepts have color indicators to show the level of recommendation for the user for each concept. The user is free to visit all the concepts even if they are not recommended at this moment to him. But for students that need guidance, SIGUE can recommend the next concept (and the best document within it) to advance in the course according to his assumed knowledge. Another aspect of adaptivity is the multilingual interface of SIGUE, currently available in Spanish and English.

2.1 Making TEA adaptive

The author tool can create a course defining the domain model associated to it. For a specific course the domain model is a hierarchy of concepts. The root node contains the general information about the course and the rest of nodes have the information about the concepts that make up the course. For SIGUE two relationships have been defined: "belongs to" and "prerequisite of". If the author defines that the concept c1

belongs to c2, this means that c1 is a sub-concept of c2. One concept can have many sub-concepts but only one super-concept. This is defined by a tree structure. The author can also define that c1 is *prerequisite of* c2. This means that to learn c2 it is necessary to study c1 first. The relationship of *prerequisite* defines a partial relationship of order. This gives an idea of the order in which concepts should be visited, which is the sequence of the curriculum.

The number of pages (URL) to describe a concept is unlimited, but there should be a main one that is shown the first time that a concept is visited. It is necessary to indicate the kind of information that each page contains (theory, examples or exercises) and the difficulty (easy, normal or hard). The difficulty is used to order the pages within a concept. The way to present the pages will be; first, the main page followed by the rest, which are shown in order from the easiest to the hardest.

Once the domain model is created and all the concepts and relations have been defined, the author has to associate the pages for each concept. The author can also define a glossary of terms for the course. A definition is associated to each term in the glossary. Optionally, a list of synonymous can refer back to the same definition. When a term defined in the glossary appears in any page of the course, a link is automatically included to show the definition of this term. This can be done in three ways: as an *hint*, this means that when student moves the mouse over the term, a textbox will show the definition; as a URL, the link will show a URL with the definition; or as an HTML page. The author just has to write the HTML code that the student will see when he clicks on the term or select the appropriate URL with the definition

Courses in SIGUE can have different modes of operation. The author decides how adaptive the course will be and must set the mode of operation accordingly. There are four predefined modes: (a) Disable all the links in the pages shown to the student. In this mode the student will be able to do the course by accessing documents only through the concept tree; (b) Leave all the links of the pages, this lets users navigate freely even in pages not related to the course; (c) Enable only the links that give references to pages that belongs to the course. This option avoids distracting the user with pages not related to the course; (d) Full adaptive. The links will be enabled according to the user model. Only those links corresponding to concepts that the user is ready to learn will be activated.



Fig. 1. The interface of SIGUE.

To construct an adaptive course, it is necessary to define the prerequisite relationship of the concepts. This definition must be as complete as possible. This will be used to guide the student correctly in the sequence of concepts to visit, establishing a partial order for the learning process.

Fig. 1 shows how the static version of TEA has been turned into an adaptive course using SIGUE. The interface is divided into two parts. On the left, the real tool is shown: the navigation toolbar, the conceptual tree, the prerequisites table, the URL table, the access to the glossary, the mode of operation selector and the buttons to save the course and generate the XML file. On the right, it shows the page that the user has found using the navigation toolbar. This page can be attached to a concept of the course. The interface is in English but the original pages of the course are in Spanish.

2.2 Studying TEA

Once the course has been developed with SIGUEAUTOR, it will be available to students in SIGUE. While connected to the web through SIGUE, the student will see the hierarchical structure of concepts created by the author. All links and forms are modified according to the strategy selected by the author for the course. Some of them will be eliminated and others will be left unchanged. The system will also include new references for the terms in the glossary, as defined by the author.

If the course is fully adaptive, a student model is created for each user. For each concept the course shows two indicators. (a) The first one shows the estimated background of the student visiting this concept, that is, if he's prepared or not to read

it, according to previous pages that have been visited. (b) The second is an indicator of the percentage of pages related to that concept that he has already visited.

SIGUE doesn't have the ability to evaluate (the evaluations are done by SIETTE), it simply make estimations of the knowledge based on the percentage of visited pages for each concept. So, if the percentage of URLs visited for a concept is less than the minimum the status of the concept is "empty"; if this percentage of visited pages is bigger than the maximum, the status is "full". The intermediary case is shown as "half-full". The status of a concept is associated to the percentage of pages the user has studied within a concept. So if the user has visited all the pages the system assumes that he has already learnt the concept. If it is "empty" the pages have not been visited yet and the system assumes that the concept is not known. This information is shown to the user by a progress bar that appears next to each concept.

The level of preparation necessary for a user to visit a concept is reflected by using colors in the nodes of the concept tree. They can be green, red or orange. The color of the node is decided using the status of the prerequisites in this way:

- *Green*: A concept has this status when all the prerequisites are shown to have their status as "full". This means when all the prerequisites of this concept have already been covered, so the concept can be studied without difficulties.
- *Red*: This will be the color if at least one of the prerequisites of a concept is "empty". This means that the user hasn't studied one or some of the prerequisites. Red indicates that the user is not ready to study the concept.
- *Orange*: This indication will appear when no empty prerequisites exist. The student has begun to study all the prerequisites but has not finished all of them. Nodes with this color could be studied but finishing all the prerequisites first is recommended.

The student model is updated after each interaction, in other words every time the user visits a page. This update is reflected in the concept tree, modifying the status and color of nodes accordingly.

The aim of SIGUE is to guide the student's navigation, and support it with adaptive annotation, but at the same time let him move freely through the pages of the course. This is why access to any page is permitted for the user even if this is not recommended (red). An important characteristic used to guide students is the inclusion of a simple planner that the student can use to get the best recommendation for the next document to view from the concept he is studying. This mechanism is designed for "two buttons users". These are the NEXT and BACK buttons.

Fig. 2 shows an example of the student's interface for TEA. This course is adaptive, and in the image the progress bar for each concept and the colors that indicate the preparation of the student for each concept can be seen. On the right, the HTML document associated with the concept and the activated link of recommended concepts and glossary terms (in this case activated by a hint).

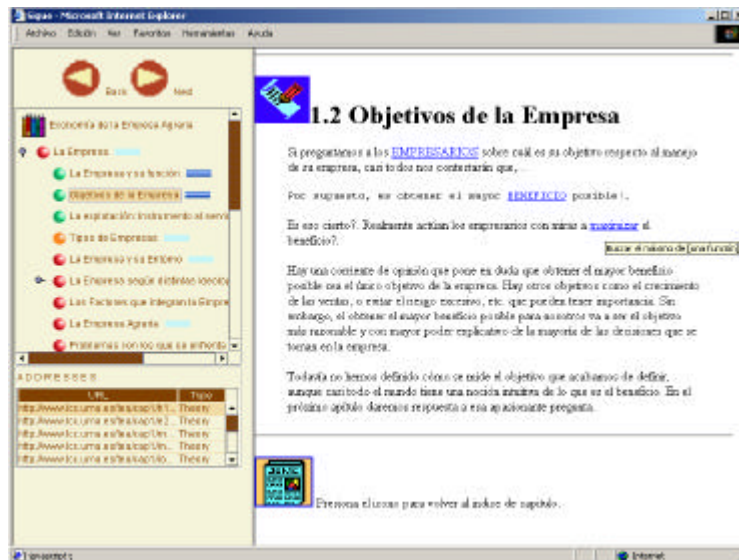


Fig. 3 Example of the student's interface for TEA.

3 Creating tests with SIETTE

SIETTE (System of Intelligent Evaluation using Tests for Teleeducation) [2] is an evaluation tool. It has been developed to be used through WWW. It has two main parts: (1) a set of *author's tools*, that allow teachers to add and update contents in the knowledge base of the system. (2) A *virtual classroom* where students can make tests to evaluate their knowledge in certain subject.

The knowledge base is composed by the concept domain (*curriculum*), the specifications of the tests and the item pools. It is hierarchically structured using a tree form. The subject is the root node and the topics are its sons. The depth of this tree is not limited by the system. The terminal nodes of this tree are the items.

Tests are configured by teachers and they are defined about topics. That is, to create a tests, teachers must indicate which topics are going to be evaluated. When a student will select this test, the test generator will show him items from all topics involved in the test, or from any descendent subtopic of these topics. Therefore, there is not any direct relation between topics and tests. This relation is established through topics.

SIETTE is an adaptive evaluation tool. This means that the selection of the next question to pose to the students, the finalization decision of tests and the mechanism of estimation of the student's knowledge, are accomplished according to adaptive mechanisms. This kind of tests are known as *Computerized Adaptive Tests* (CAT) [3].

SIETTE, as well as the most of CAT systems, uses as an inference machine a psychometric theory called *Item Response Theory* (IRT) [4].

IRT is based on the hypothesis that the answer given to each item of the test, probabilistically depends on the knowledge level. As a result, conditional

probabilities of the successful answer to the item by a student with a certain *knowledge level*, can be easily calculated for each item. This probability is expressed by means of a function $f : (-\infty, +\infty) \rightarrow [0,1]$, named *Item Characteristic Curve* (ICC). The calculus of the ICC can be accomplished by several models. SIETTE uses a model of three parameters based on the logistic function [5].

Also, in IRT, the knowledge level of the student is estimated using the response to each item of the test. There are several methods to get this value. In SIETTE a Bayesian method [6] is used. In this method, the probability distribution of the student's knowledge level is calculated by the Bayes' rule. Also, it is assumed that the knowledge level can only take K discrete values (from 0 to $K-1$) because of the high computational cost of the calculus. Thanks to this consideration, the Bayesian method for the estimation of the student's knowledge level can be simplified to a vectorial product of ICC vectors with the *a priori* normalized density vector.

SIETTE does not need to establish priority relationships between topics. That is, there is no need to explicitly indicate if items from a topic must be posed to student before the items of other topics. If the characteristic curves of the items are well calibrated [7], thanks to the adaptive selection mechanisms, the test generator will show to the students, the most suitable item according his estimated knowledge level. This means that, if a student fails an item of difficulty d , the next item which the generator will pose him, will have a difficulty lower than d . Generally, the calibration process of items will make that items from the firsts topics of the curriculum, have lower difficulties than items of the latter topics.

The finalization criterion is configured by the teacher in each test. Through test editors, he must indicate a minimum and a maximum number of items. These values set bounds to the number of items that may be posed to the students. If a student has taken the maximum value of items, the final estimation process of his knowledge is forced. This ensures that test will finish, although the finalization is not satisfied.

3.1 The test of TEA

In SIETTE a subject of Agrarian Economy has been defined. Its *curriculum* is composed by 14 topics. Each one of this topics corresponds with one of the chapters of the TEA tutorial provided in SIGUE. Currently, there is a total number of 84 items stored in the knowledge base. Each topic has approximately six of these items that are used to evaluate the knowledge of the student about this topic.

A test for each topic has been created too. In SIGUE, once the students have studied one topic, they can directly access to the corresponding tests in SIETTE, and evaluate their proficiency in it.

Also, a global test of Agrarian Economy has been defined. This test allows to simultaneously, in the same test session, obtain an estimation of the student knowledge level in each one of the topics, as well as in the whole subject. This test is useful like a pretest. That is, before the instruction process, and to obtain a initial estimation of the knowledge level, students may accomplish this test. This contributes to give a better instruction to students from the beginning, since the system has a good initial approximation of the proficiency of the student, and it must not suppose which is the initial knowledge level.

All tests has been defined for twelve knowledge levels. Therefore, at the end, system will give to a qualification between 0 and 11. All items are multiple choice items, *i.e.*, items where students may either select only one response of a set of options (obviously, the number of options must be greater than one), or not select anyone.

Fig. 3 shows an item presentation inside a test session (a), and its correction (b). Each item is composed by the title, the stem and the set of options. Once the student has pushed the *Send Response* button, the system shows the correction of this item. Correct option is marked in green. If student has selected a wrong option, it will be marked with a red cross.

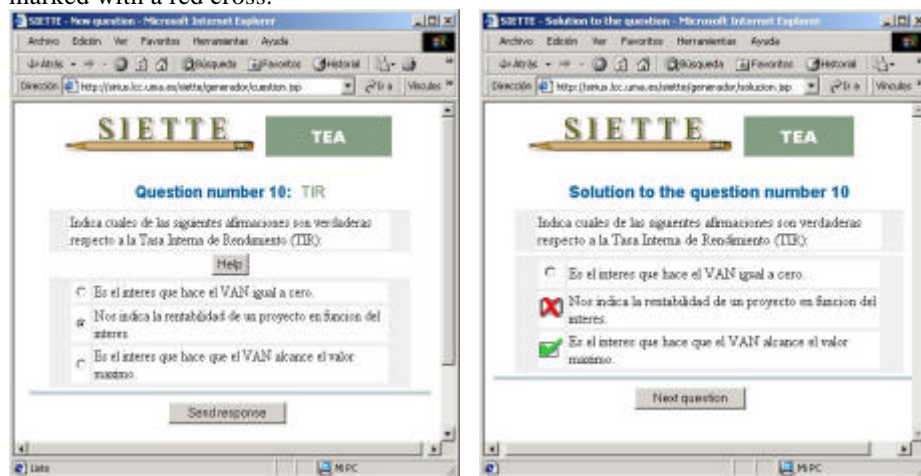
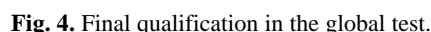


Fig. 3. An item posed by the test generator and its correction.

Fig. 4 shows the final qualification of the student in the test of the whole subject. As it can be seen, the system provides a detailed set qualifications for each topic. Also statistics about the number of items posed to the student are given, as well as the number of items that have been successfully answered by the student. Note that the estimated knowledge level does not meet with the number of items successfully passed. This is due to the final qualification has been inferred by an adaptive criterion. At last, a pie chart with the percentage of topics posed from each topic, and the distribution curve of probabilities of that the student has each one of the knowledge levels, are presented too. Note that the value with the highest probability corresponds with the estimated knowledge level.



4 Integrating SIGUE and SIETTE

The integration of these system can be accessed in <http://www.lcc.uma.es/SIGUE/TEA>.

In the navigation process through the contents of the tutorial, the SIGUE system will recommend the students which are the best pages to visit, to improve his knowledge about the subject. This recommendations will be done taking the estimated knowledge level as a starting point.

After the finalization of the study of the contents of each topic, the system will offer the student the possibility of making a test to evaluate his proficiency in this topic. This test is an adaptive test about the concepts that have been studied in this topic.

If the student does not pass this test, the system will recommend him to repeat the study of this topic, although he can take freely the decision to continue the instruction or repeat the previous topic.

Once the student has visited all the pages of the tutorial, the system will offer him to make a global test of the whole subject. Through this test, students can check if they have assimilated correctly all the notions explained all along the tutorial.

5 Conclusions

TEA was conceived as a Computer Aided Educational System for the teaching of Agrarian Economy. Even though it was initially designed to overcome the classical lacks of hypertext education, by using graphical and textual clues to improve the user orientation, the navigation through the course could not be controlled.

To solve this problem, this educational system has been made adaptive. By using SIGUE, the navigation process of student is guided through codes of color. Also, system recommends at each time which is the most adequate topic to visit.

Also, a set of adaptive tests have been include in TEA through SIETTE. There is a test for each topic, which allows students to evaluate their knowledge about that topic. In these CATs, each item is selected in terms of the current estimated student's knowledge level. The main advantage of CATs is that they reduce the number of items required to estimate the student's knowledge level.

This work has mainly supposed the integration of two web-based adaptive systems. One system to guide the student in the learning of concepts, and other system to evaluate his proficiency in these concepts. By means of this integration, students can access to both functionalities through the same web system. The student does not need to know that he is accessing to two different systems. This makes easier the instruction process.

SIGUE and SIETTE can be tested in <http://www.lcc.uma.es/SIGUE> and <http://www.lcc.uma.es/SIETTE> respectively.

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