Online automatic examination system for digital circuits

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Abstract— **In the era of globalization and the Internet, the Universities must reshape curricula, to include asynchronous e-learning technologies in order to remain competitive and attract the best students and teachers. A technology that should be added to the arsenal of infrastructure programs is tele-examination. In this paper, the construction of a complete online automatic examination system of digital circuits is analyzed. Specifically, open source software was used to construct a dynamic website for automated student examination in order to support asynchronous e-learning, supported by an RDBMS database. The application development language is the dynamic programming language for web applications PHP, while we use the PDO extension for a safe and secure connection to the database. The system supports multiple classes and multiple categories for each lesson, which in turn can contain a number of tests, all of which are managed by the administrator (professor) through the web application. Moreover, questions and answers are constructed randomly by a generator program developed in C language. The professor can supervise an active test in real time, and modify the time period of the submission for each student. After the submission of an exam he has the options to grade the text and file type answers that were included in it, to oversee an analytical list of the answers given by each student and finally to produce PDFs with those answers and view various charts about the results. The exams are accessible either by authenticated students or by students who have received a personal identification number (token) or by free users with limited privileges.**

Keywords— *website; automatic examination system; e-learning; student examination; open source software;*

I. INTRODUCTION

As computer technology is constantly evolving, education systems cannot remain firmly devoted to the old traditional ways of learning. The term "e-learning" becomes more and more widely known through its numerous applications in the field of education. One basic aspect of e-learning is the online examination. The traditional examination procedure requires a great number of human resources, stationery, and investment of time in composing examination questions. In contrast, the new models of e-learning and online examinations have numerous benefits for both the educator and the students. With online examination, the professors supervise more easily the students' progress and set examinations fluently. Some courses have four examinations per semester, therefore without new technology developments, the workload of the

examiners would be skyrocketed. Besides, students can take the exam from a distance when they are prepared.

The main purpose of this project was the development of an integrated system that generates examination papers with random questions about the curriculum of digital circuits' courses. This system consists of a database, a website and a questions' program generator. Each examination becomes unique, thanks to the numerous random questions provided by a database of questions, which is produced by a tool program. Furthermore, it should be mentioned that an extension of the website is the anonymous "free exams" concept of the examination tests for students to practice regularly and check the obtained knowledge.

The rest of this paper is as follows: Section II refers to related work and existing projects. Section III, presents in detail the design and development of the online examination system, from the creation of the database and the website to the development of the questions' program generator. In Section IV, an evaluation of the system is carried out and finally, in Section V the conclusions and future plans for this work are presented.

II. RELATED WORK

Every education level and especially Universities are trying to incorporate ICT (Information and Communications Technology) and e-learning in an attempt to update and modernize their teaching methods. According to Kyong-Jee Kim and Curtis J. Bonk [1], the future of online learning is very developed and promising. A vital part of teaching methods, is the evaluation and examination systems (EES). Traditionally, EES are accomplished using "pen and paper" methods, but nowadays there is a significant development in online examination systems either from software companies with commercial codes or from academic researchers and open source codes.

The last couple decades, the research carried out contribute to the better education of the students. The L.C. McDermott's and P.S. Shaffer's research [2], [3] offered a comprehensive curriculum development for courses in the field of electrical circuits. Another later useful research and development in the education of electrical engineering, by P.V. Engelhardt and R.J. Beichner in [4] and C.H. Kautz in [5] should be mentioned.

Specifically for the examination systems, a few notable were developed [6], [7], [8] and they were used use in various fields and courses. In [6] the authors Mohammed Issam Younis and Maysam Sameer Hussein, presented an integrated system for online examination. In contrast with our own, the administrator chooses the questions and they are not given automatic. The system that is designed in [7], by LV hai-yan, Lv Hong, Zhou Lijun and Zhang Jie, facilitates the examinations for military academies and based on their curriculum. In [8], T. M. Fagbola, A. A. Adigun and A. O. Oke are presented the development of an examination system for Universities. In contrary with other, our work targets engineering discipline and digital systems, with a great asset; the generator that produces random questions for the examinations.

Other projects were focused on the analysis and the design of algorithms for the automatic generation of multiple choice questions [9], [10]. In [9] the system that is presented by Kapil Naik, Shreyas Sule, Shruti Jadhav and Surya Pandey, generates only question papers, and not the questions. So a data bank with questions is needed. The automatic generation that is analyzed by Andreas Papasalouros, Konstantinos Kanaris and Konstantinos Kotis, in [10] generates multiple choice questions, but only from domain ontologies.

III. DESIGN AND DEVELOPMENT OF THE SYSTEM

Our system architecture consists of 3 sections, as is illustrated in figure 1: a frontend, a backend and a database server.
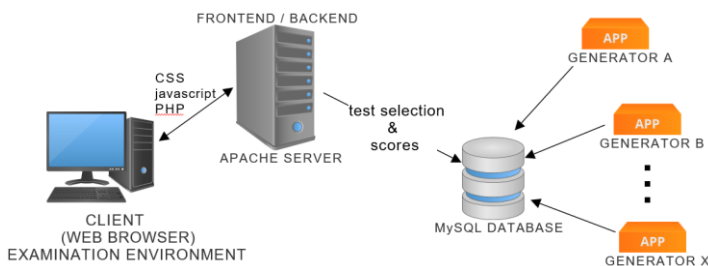

Fig. 1. System Architecture

For the design of the system we used these technologies: the server-side scripting language, PHP, combined with elements of the dynamic, interpreted programming language JavaScript and the use of client-side Ajax techniques, in order to send data to and retrieve from our server asynchronously (in the background), CSS for the styling of the web pages and the relational database management system MySQL. The PHP extension, PDO, was used as a database abstraction layer. Our first step was the analysis of the system, its user's roles and its requirements. After this, we design and optimize the database. The subsequent step was the website development. Moreover, it is important to be mentioned that the system supports text based CSV (comma-separated values) files, as a form of input. This enables us to construct generators in various programming languages that produce CSV output files to enrich quickly and easily our examination database with a vast number of random questions.

A. Design of the Database

The basic principle to design the database correctly is to find the classes of users of the system that interact with it. In the system there are five types of users:

- A global system administrator.

- An operator/ teacher.

- A student, who has logged in the system.

- An anonymous student, making use of a token.

- A fully free user, who hasn't used any kind of log in details or a token.

Following the analysis of the requirements of the examination, we designed the database. Initially, there was an attempt to schematically reflect the interaction of the data on the website. The resultant scheme illustrated ten entities (users, teachers, departments, classes, categories, questions, tests, tokens, results and messages). Thus, a teacher can have classes in a department. Tests are generated by questions belonging to a lesson and a specific category. In turn tokens are created for a particular exam. Finally, the users produce results by submitting an exam and, as we already mentioned, they can send a message to teachers with a specific question, if they think it needs further explanation. Of course this scheme reshaped continuously during the development of the system, as needed. As it was enriched with new elements, the final database structure that emerged includes fourteen tables. Among them are, a table that holds information that is used to produce the graphs of the system, and a table in which, all information about the uploaded attachments is stored. Teachers can also upload images, audio and text files as an attachment to a question and its options as well as to a test. Students can upload all kinds of data too, as an answer to a specific question type, which is a file type.

B. Development of the System

After considering all the requirements, the next step was the implementation of the system. In the current section, we present the key points of the website's programming, such as the PHP, JavaScript and Ajax techniques that were used. Also, we analyze the use of PDO for the security of the system and we explain how the graphs are created.

Every input on the login page is sanitized using the "filter_input ()" function to ensure that no hacking attends are feasible.

Another security enhancement, which is the most effective form of sanitization to prevent SQL injection, is the configuration using PDO. Using parameterized queries, the query is separated from the data, so as to remove the threat of first class SQL injection. The SQL injection is a technique where malicious users can inject SQL commands in an SQL sentence, through an input of the website. The SQL commands that have come from an injection can change the SQL statement and endanger the safety of the application. But with the proper implementation of PDO, using prepared statements, placeholder symbols are used rather than the data itself, so no additional information can be included in the statement. A typical SQL statement using PDO has the syntax illustrate in figure 2.

```
1. $current_datetime = date('Y-m-d H:i:s');

2. $test = $_GET['tid'];

3. $query = $dbconn->prepare("SELECT * FROM tests
   WHERE id= :tid AND start_date<= :cdate AND
   finish_date>= :cdate");

4. $query->bindParam(':tid', $test);

5. $query->bindParam(':cdate', $current_datetime);

6. $query->execute();

7. $rows = $query->fetch(PDO::FETCH_ASSOC);
```

Fig 2. Example of PDO usage

Finally, our backend system has been optimally designed to use a limited number of SQL queries to the database and thus allowing it to scale to large numbers of simultaneous examinations. We estimate a dual core VPS system can handle up to 2000 simultaneous student examinations without any latency in the SQL queries.

C. Development of the Questions

The generation of the examinations' questions is a custom application that we developed, as a proof of concept. The generator communicates with the website using CSV files which are imported to the database for enrichment. It supports the generation of up to 25 categories of questions that cover issues of courses relevant to digital circuits. The categories vary from conversions to different numerical systems and logical operations to questions for flags and commands of assembly 8086. A complete list of the categories is below.

- Converting binary number to hexadecimal and vice versa.
- Converting signed or unsigned binary number to decimal and vice versa.
- Converting signed or unsigned decimal number to hexadecimal and vice versa.
- Converting binary number to 2's complement and vice versa.
- Summation of two binary numbers.
- Subtraction of two binary numbers.
- AND operation of two binary numbers.
- XOR operation of two binary numbers.
- NOT operation of two binary numbers.
- OR operation of two binary numbers.
- NAND operation on two binary numbers.
- NOR operation of two binary numbers.
- AND, XOR, NOT, OR, NAND, NOR operations of hexadecimal numbers.
- Width for signed or unsigned numbers in 2's complement for specific bitwidth.

- Converting octal number to decimal and hexadecimal and vice versa.
- Converting binary number to 1's complement and vice versa.
- Flags SF and ZF (assembly 8086).
- Flags CF and OF.
- SHL command for 8bit and 16bit registers.
- SHR command for 8bit and 16bit registers.
- SAR command for 8bit and 16bit registers.
- ROL command for 8bit and 16bit registers.
- ROR command for 8bit and 16bit registers.
- RCL command for 8bit and 16bit registers.
- RCR command for 8bit and 16bit registers.

The questions differ from each other to the data numbers, i.e. with different random numbers, the program produces different questions with one correct answer and four random wrong answers for each question. As an example, in figure 3, the algorithm flowchart of a category function is presented. Specifically, we choose one or two random number(s) and convert them from decimal to binary. Then we perform some computations to find the right answer and the four wrong answers are chosen randomly. Finally, the function prints the question and all the answers. The exact algorithm of each category may vary for each purpose.
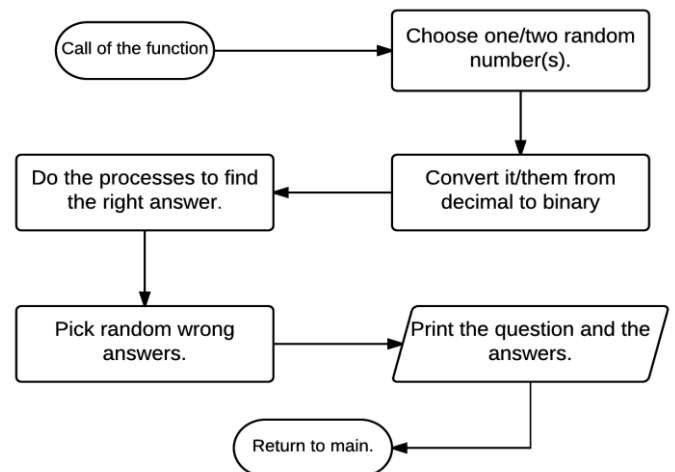

Fig 3. The algorithm flowchart for generating questions for one of the 25 categories

The program was developed in C language and consists of the main function, functions for each question category and auxiliary functions, which are called by the program in many category functions (conversion to binary numbers, print of a binary number, etc.). The executable produced takes the following four parameters: 1) the number of the questions that the user wants to produce, 2) the number of the categories, 3) the maximum number of the random numbers and 4) the number that the user wants the questions' code to start. In case that the user inserts the parameters incorrectly, an error message with a help menu is printed.

Also, it is should be mentioned that the program was carefully designed to check inputs in order to not have segmentation faults and core dumps. When the executable has the correct parameters it runs, outputs the questions into CSV files with the format of iexams (compatible with the website) and terminates. For more questions of another category, it must be re-executed.

To illustrate the quality of the random generated digital design questions, we have made available for anonymous users, a test at: arch.icte.uowm.gr/iexamsII/teste.php?tid=48 . Every test is unique for every visitor, meaning that the questions as well as the order of the answers are different. We have also enabled the display of the correct answer, in order to provide feedback to the examinee to help him understand better the fundamentals of digital design. A sample question is presented in figure 4.

Ενότητα: 08

(08.61) Ποιο είναι το αποτέλεσμα της πράξης XOR με τους αριθμούς 011001b και 001111b?

○ 010101b

○ 011001b

○ 010110b

○ 000111b

○ 001011b

Υποβολή   Παράληψη

Fig. 4. Screenshot of a question

The system is in production stage and we can provide the source code to instructors who would like to incorporate the electronic examination of their curriculum. Even though out tool generates questions with the greek language, the source file can be easily changed to generate questions to every language.

IV. EVALUATION

The website has been used as part of Computer Architecture laboratory of our department from 2014 until now flawlessly, and the results were satisfying. A large number of students who took this course, answered to opinion polls for a feedback on the website. The conclusions were satisfying and with positive comments. The website was used on a daily basis and helped student's study, especially at the end of the semester when they had their final exams and they wanted to practice. The results of their final examinations were very promising and with good results. Furthermore, the results of the examinations are uploaded online automatically and instantly by the system and they are visible to the professor and each student. Thus the examiner doesn't spend valuable time to review the examinations and the examinees could learn their grades directly from the same website. Until now, the website has not any problems at all, even though it has been used for more than 120 students per semester.

V. CONCLUSION

In summation the analysis of the construction of an online automatic examination system is presented in this paper. The main purpose of this system is a contribution to e-learning. The reason that makes this system different from other related work is oriented to examinations of digital circuits' courses. The key elements of its development are the following:

- Website's development language is PHP. PDO extensions are used for safety connections.
- Construction of a MySQL database for the system.
- Design a program that generates random multiple choice questions.
- A great number of students are supported by the system.
- The examination tests are created automatically.
- The evaluation and the feedback of the users are very positive.

The system is a valuable asset of the ARCH laboratory of our department. System's evaluation by students is positive. Future work could lie in the development of more program generators. Moreover the support of other similar courses is on our planned roadmap.

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