Dominik JESKE, Maciej KRASUSKI, Rafał STRYJEK, Sławomir WIAK

Technical University of Lodz, Institute of Mechatronics and Information Systems

Modern distance examination as part of distance learning – the E-matura project

Streszczenie. *Artykuł przedstawia system do prowadzenia nowoczesnego egzaminowania na odległość, który jest jednym z elementów e-learningu. E-matura zawiera ważne funkcjonalności, takie jak komputerowe wspomaganie diagnozy matematycznej absolwenta. Dzięki wykorzystaniu najnowszych technologii autorzy stworzyli nowoczesny interfejs, który pozwala na tworzenie e-egzaminów z pytaniami zawierającymi obrazy, animacje, filmy, nagrania dźwiękowe i otwarte pytania. Autorzy musieli również sprostać wyzwaniu zapewnienia wysokiej dostępności systemu.* (***System do prowadzenia nowoczesnego egzaminowania na odległość***)

Abstract*. This paper demonstrates a system for conducting modern distance examinations - as part of distance learning. E-matura includes several important features such as computer-aided mathematical analysis of graduate characteristics. Using the latest technology, the authors have created a rich interface - it allows the creation of e-examinations with questions that contain images, animation, video, sound recordings and open ended questions. The authors have also had to meet a challenge concerning the requirement for the examinations to be highly available.*

Słowa kluczowe: E-matura, Nowoczesne egzaminowanie, Egzaminowanie na odległość, E-learning.
Keywords: E-matura, Modern examination, Distance examination, E-learning.

Introduction

The number of virtual learning environments is increasing. New teaching models and tools incorporating e-learning already have been successfully exploited by a large group of universities and other professional institutions involved in the education process. One important element of the educational process is the examination. Modern e-learning platform should have an effective unit for examination. The E-matura is created as a tool to fulfill all the tasks of e-examinations.

The E-matura system was created under Direction of Professor Sławomir Wiak at the Technical University of Łódź and under the auspices of the Ministry of Education. Several thousands of students from all over Poland took the matriculation examination in mathematics at the same time via the Internet. IT corporations, Microsoft and IBM, commited themselves to the project supporting the programming team.

Modern GUI

Today's systems for conducting examinations focus primarily on the so-called test questions known as closed questions – with set of possible answers for each question. Thanks to modern technology such as Silverlight, in the E-matura system questions could include elements such as interactive animations, interactive areas for drag and drop items and for highlight the answers. These few examples show that the possibilities of a modern examination go beyond the traditional forms of the test examination. Further, using animation and appropriate graphics, an examination becomes more friendly to people who are often stressed during the test.

Figure 1. Question with highlighting a range of numerical values

The use of modern technologies give new opportunities in e-learning, as demonstrated in this team's another project called IMSI e-platform. There are features which improves effectiveness of learning such as audio/video streaming and chat. What is more, each student can add note directly to the lecture file by add text note or highlight some part of text. There is also special note view with virtual sheets of paper with text notes, drawing and audio notes. When the teacher draw something on the board – its content shows up in student applications. Enabling 3D mode for lecture file causes that the student has more screen space.

A rich interface makes learning, teaching and examining enjoyable.

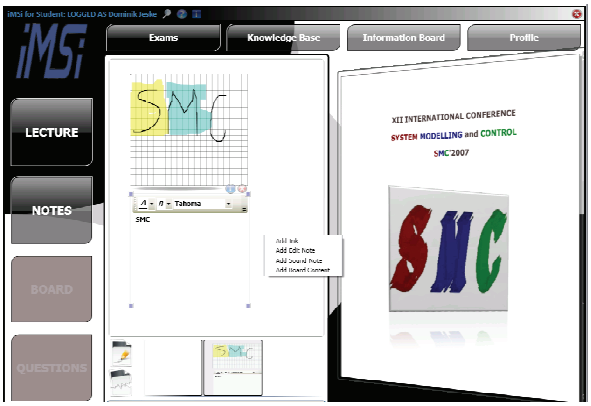

Figure 2. Lecture in 3D with notes mode

Accessibility

We are working to enable support for accessible content, by programming actions or by set of Silverlight behaviors. The project will meet the standard of WCAG version 2.0.

This standard includes a variety of techniques which include specific authoring practices and examples for developing more accessible Web content[1]. These techniques relate to the possibility of controlling the application from the keyboard, to increase the font size, stop and booting animation. What's more, contain information about the guidelines for the use of color in an application, a short text alternative for controls that do not otherwise contain text.

Computer-aided analysis of graduate characteristics

During each exam – in 2009, 2010, 2011 – 600 000 answers were collected. If students answered a given question several times, changing their reply, then the system recorded all the steps. The time taken to produce each answer was also registered. There were three sets of questions and answers implemented. For the purpose of research, questions form simplest to the most difficult Or from the most difficult to the simplest and randomly. Further, two versions of the answers were user: in the first the correct answer to 70% of the questions was by selecting B or C – 30% is A or B. In the second, this order was completely random.

Table 1. Exam results for different versions – for All students

	Points B C answers superiority distribution		Uniform answers distibution	
	Points	Points percentage	Points	Points percentage
From easier to harder	23,27	51,26	23,30	51,33
From harder to easier	22,41	49,35	23,99	52,84
Random	22,91	50,46	23,25	51,23
Summary	22,88	50,39	24,55	51,89

Computer-aided diagnosis of mathematical graduates can be divided into groups of end users: students, teachers and authorities. Teachers will see results for the whole class and for each student. Authorities will be able to analyze results at type of school, city, region and country level. Students results will be compared with the class, school or whole country. Computer diagnosis will indicates the parts of program that need additional work. Time spent in a given question, the number of inputs in question, for which the entry in question was given the correct answer - give a very large, inaccessible until now, analysis capabilities. The analysis can take place at the level of student, class, school, type of school, city, region, and with a survey after the exam, even the blood group.

During the survey students answer several questions, covering such issues as: whether they were attending the tutoring, who was the authority, how much time per day they spent at the computer using the Internet, if both parents work, whether parents help them in their learning.

Table 2. Sample exam results for analyzes

Question		Time spent to solve question [min]				Points for question				
Category	number	avg	min	stddev	median	avg	min	max	stddev	median
Open questions	1	14,7	0,1	19,54	10,1	0,6	0	2	0,90	0
	2	6,9	0	10,06	4,1	0,7	0	2	0,82	0
	3	6,1	0	5,38	5,6	1	0	2	1,00	0
	4	6,6	0	4,92	5,4	1,2	0	3	0,76	1
	5	2,5	0	4,05	1,9	0,1	0	2	0,49	0

E-tutoring

Currently, we design a subsystem to an e-tutoring. Students without leaving home at any time will be able to test their knowledge on the graduation test in similar form to the appropriate exam. Each student will be able to solve tasks in mathematics from the area, which will be indicated in the diagnosis as requiring additional learning. What's more, the teacher will be able to assign additional tasks to the student and the system will check the correctness of their answers. The teacher will not have to check the homework.

High availability

The classic examination system, running in the on-line environment is activated on a single Web server, which handles all the traffic generated by this and other applications that are installed on the computer. This solution works in most cases because the average numbers of people who use the Web server at any one time are not able to overload the server resources. In a situation where tens of thousands of people are referred to a single server at the same time, overload is unavoidable. It is because any connection to the server requires a certain allocation of memory and CPU time.

To meet the requirement of high availability for the examination, the solution based on the so-called load balancing was applied.

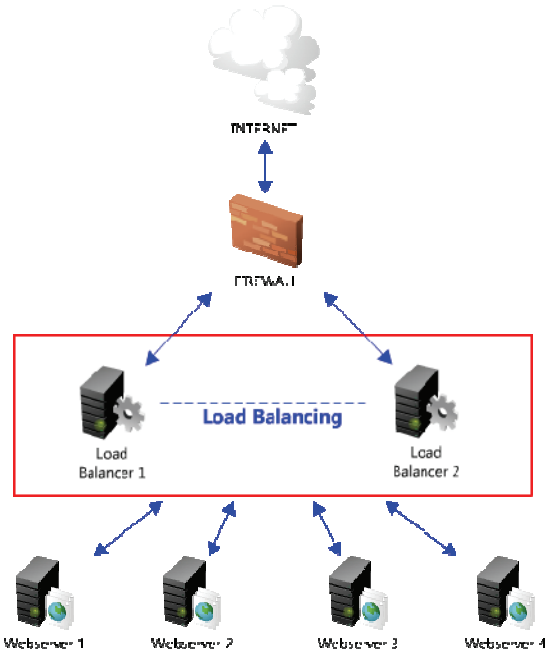

Figure 3. Load balancing

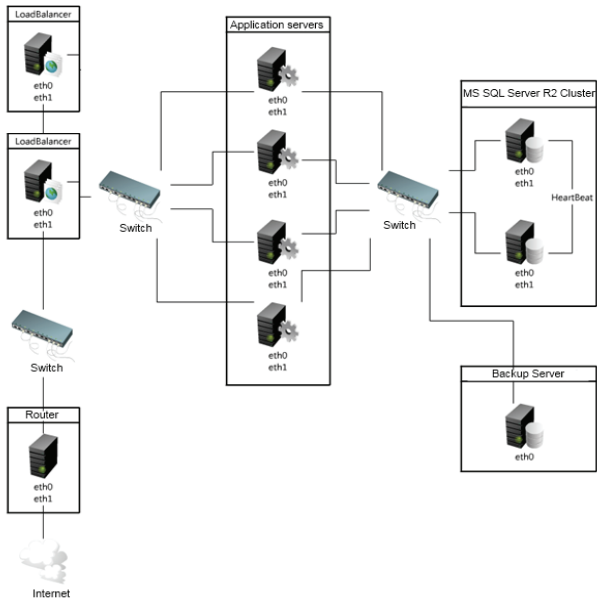

Figure 4. System architecture

The solution is to build a cluster of servers in which one can distinguish two main parts. The first one is a computer constituting the AP to the examination. All connections are directed to this computer, but they are not directly supported, but only transmitted to the computers in the cluster. Based on the selected load management algorithm, this server redirects traffic to the least loaded server in the cluster. This solution is highly scalable and allows for virtually unlimited expansion of the cluster. The only limitation is the Internet bandwidth at which the communication takes place.

Data Safety

An IT system, which stores and processes the personal data of its users, must ensure very tight data security. The E-matura project has to store detailed information about the users (Name, Surname, Personal ID), i.e. students and teachers who participate in the project. Storing these data is required in order to identify each user of the project by the financial institution funding this project. Moreover, classified data such as examination questions and survey questions, which are asked during examination, are also stored in E-matura.

In the E-matura project, an SQL Server 2008 R2 Microsoft database was used, which provided several possibilities for protection of data against unauthorized access. Taking into account two basic features (the rate of application performance and security of classified data security), it was decided to encrypt data at a line level using the AES algorithm. Only table columns that store sensitive data were encrypted to avoid slowing down the whole database. By using encryption, even people with physical access to data are unable to use them without the proper decryption key.

When developing a Web-based project, which involves users who are very determined to pass the examination, other safety-related factors must be taken into account. One known problem, which often occurs in these types of systems, are SQL injection attacks. These attacks are very common in systems where the business logic used to retrieve data from the database is located within the application. An example of a malfunction can be the creation of a mechanism to login in, which queries about the user's existence are built into the application and then run as a dynamic SQL in the database. In this case, an unauthorized person can affect on the appearance of a built query by typing additional SQL commands. In this way, the system will check, if the password is correct and then execute the hacker's command.

To avoid this problem and to prevent access to data directly from the application, all communication between the Web application and the database must be done through stored procedures. In this way, the user cannot get to the tables and data, because the stored procedure which provides such access, is not available.

Network Security

The client application communicates with the server part via a network service based on Windows Communication Foundation technology, version 4.0. This technology, using open standards such as HTTP and SOAP, provides the functionality to client applications. In order to ensure secure communication between the client and the server, an SSL, which allows the security of the system in two dimensions, has been used:

- Verification of Application Server;
- Encryption of transmitted data.

Verification of the server is based on a system of certificates through which it is possible to check an entity identified by a given certificate. The certificate is issued by a special certification centre at the request of an applicant.

Each certificate includes a pair of keys: private and public, so that it is possible for an asymmetric encryption of data transferred between client and server. During the communication between the application server and the application installed on an end user's computer, keys are used to encrypt and decrypt transmitted information. By using this solution the data sent between the client and the server cannot be overheard by a third party.

The firewall, separates servers that are within the internal network from the so-called external world or the global Internet. The firewall allows for locking of the computer's ports on which the services are not operating, in order to increase safety and to not leave loopholes for malicious software that could get through such ports to the internal network.

Authentication involves checking whether the person is who he/she claims to be. By the authorization process, the system checks which resources/functionality the user is authorized to access. In the E-matura system, authentication is based on the username and password, which are checked when the user logs into the system. If the user gives the correct data, as a result of this operation, he/she will receive a specially-called token-generated number that is assigned to the current logon session.

This token is used to authenticate all Web service methods that provide a unique communication layer between the client and the server. By using a token, the username and its password are not sent with each request to a Web service, and this increases safety by reducing to a minimum the transmission of confidential data to the user. Additional protection is the life span of the token counter. Each token has a set life span that is incremented each time the site is accessed. If the service using the generated token is barred because of its invalidity, any subsequent attempt to gain access to the site returns an error and redirection to the login page. With this approach, a token captured on a victim cannot be used on another computer or the same computer in another session.

Secure registration paths

In order to assure safety in IT projects like this, users can't register to the system by so called open registration process. In traditional registration systems user can register to the system by its own and this loose some security leak in the system allowing unauthorized persons to enter to the system pretending to be a student. In e-Matura, registration process is divided into couple registration procedures. When school wants to join to our program - contact with us by phone and sends some confirmation papers. After confirmation process, school is delegating person which is responsible for administrate users in E-matura system. This person use login and password which is send to him by email provided in confirmation papers from his school. After login to the system delegated person is responsible to register every computer in school which will be used in exams process. When computer is verified to be ready to handle exam, system count this computer in total verified computer sum. After testing process finishes teacher can register user accounts for counted computers minus two for special situations (for instance computer can crash during an exam). After filling students data, user accounts are ready to use but passwords for those accounts are send to delegated teacher in the day of exam to prevent security leak.

Conclusions

E-matura is not only a modern system for conducting examinations at a distance, it is also a computer-aided mathematical tool for analysis of graduates. The collected data can be used to analyze at different levels of detail. The project is under continuous development. After its end, the product will be fully ready for use on a large scale, but the goal is not just to create a reliable system to conduct examinations at a distance. In 2013, the product will be fully ready for use on a large scale.

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***Authors**: Professor Sławomir Wiak, Ph.D.,D.Sc, Technical University of Łódź, Institute of Mechatronics and Information Systems, Stefanowskiego 18/22, 90-924 Łódź, E-mail: Slawomir.Wiak@p.lodz.pl; mgr inż. Dominik Jeske, Technical University of Łódź, Institute of Mechatronics and Information Systems, Stefanowskiego 18/22, 90-924 Łódź, E-mail: Dominik.Jeske@p.lodz.pl; mgr inż. Maciej Krasuski, Politechnika Technical University of Łódź, Institute of Mechatronics and Information Systems, ul. Stefanowskiego 18/22, 90-924 Łódź, E-mail: Maciej.Krasuski@p.lodz.pl; mgr inż. Rafał Stryjek, Technical University of Łódź, Institute of Mechatronics and Information Systems, Stefanowskiego 18/22, 90-924 Łódź, E-mail: Rafal.Stryjek@p.lodz.pl*