The *E-matura* project yesterday, today and tomorrow - challenges and opportunities

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ABSTRACT: This paper describes challenges that must be addressed when designing high-availability systems, such as matriculation examinations, which are used by several hundred thousand people at the same time. The methods presented demonstrate how to provide users with continuous and fast access to the system and how to protect this system from unauthorised access by a third party. These issues and topics are presented and discussed in this paper using the *E-matura* project as an example. The *E-matura* system has been designed and built to cope with a heavy load, which is generated by a huge amount of information and data generated by students who sit for the examination simultaneously.

INTRODUCTION

Systems used for providing examinations at a distance must meet stringent requirements for security and high availability from both the programming and from the organisation. To meet this requirement in the *E-matura* project, a range of mechanisms and features that provide a high level of data security have been used. This paper presents the opportunities and challenges faced by the creators of *E-matura*.

A LARGE NUMBER OF USERS AT ONE TIME

One of the fundamental challenges faced in the designing stage of *E-matura* was ensuring high and uninterrupted availability of the examination. During the first attempt to run this examination, access to it was shared by about 3,000 students and the system, with this application, was composed of one application server and one database server. At that time, it was an adequate configuration but it was not sufficient for the future because the number of high school graduates can reach hundreds of thousands.

In cases when thousands of users are referred to the one server at the same time, each connection to this server must be allocated a certain amount of memory and processor time. To ensure the examination availability remains high, the so-called *Load Balancing* solution was used. This solution is based on building server clusters, which can be distinguished in two main parts.

The first part is a computer, which is an access point to the examination. All connections are directed to this computer but they are not served directly but only transferred to computers in the cluster. On the basis of the load management algorithm that is chosen, this server redirects the traffic to the least loaded server in the cluster.

This solution is very scalable and allows unlimited server extensions. The only limitation is the Internet connection at which communication takes place. The additional feature, which this server can meet, is decoding the SSL - encrypted message and passing it forward in the decrypted form, which reduces the load on the target servers, but with large numbers of connections, it can overload the traffic balance server.

Due to the use of the above technique, the scalability of the system is practically unlimited and enables management of thousands of users in a dynamic way. The use of the cluster also ensures the permanent availability of the application because the failure of any of the elements of the cluster does not affect the operation of the system because it can be swapped for another server in the cluster.
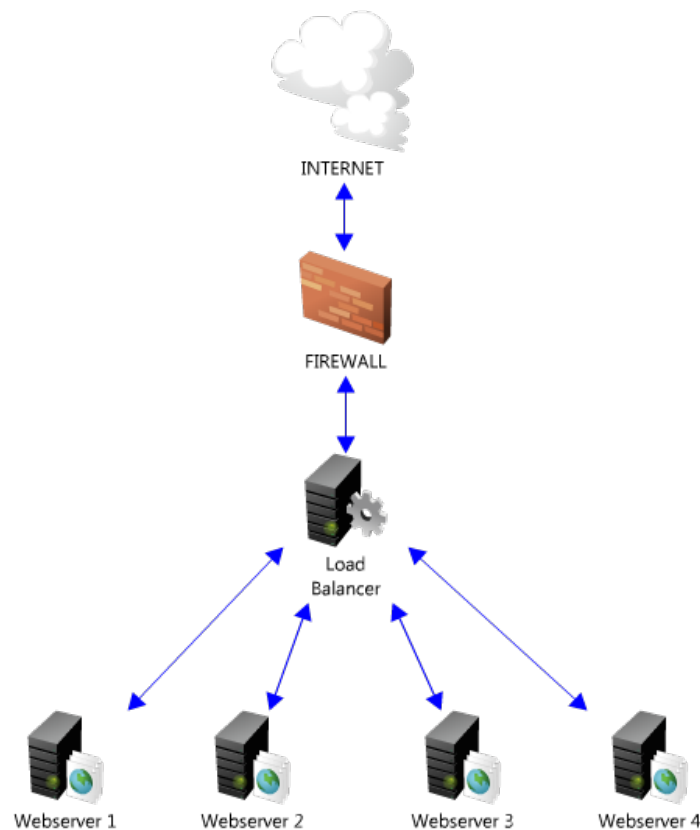
Figure 1: The cluster of servers.

ENSURING PROTECTION

One very important role in designing the examination system is to ensure security during data transmission. To ensure secure communication between the client and the server, SSL technology was used, which helped to secure the system in the two areas:

- Application server verification - each application available through the SSL protocol uniquely identifies the person/system for whom/which a certificate has been issued. Thanks to this solution, the user can check if he/she is acting with the original server;
- Transmitted data encryption - each SSL certificate contains a private and public key, and thanks to this, it is possible to achieve the asymmetric encryption of data transmitted between the client and the server.

The encryption of the connection and the server identification through a certificate, which is issued by the trusted certificate centre, does not provide complete system protection. The user of the system knows that he/she communicates with the original server and the data that he/she introduces does not fall into the hands of a third party. However, the client himself/herself must be properly verified to decide which resources he or she needs to have access to. His/her authentication and authorisation need to be conducted in order for there to be proper user verification. The authentication involves checking if the person is who he/she claim to be, so his/her login name and password are checked. The next step contains the authorisation process that includes checking to which resources/functionalities the user has access rights.

In the *E-matura* system, the authentication for access to the system is built on giving a login name and password, which is checked during logging into the system. If the user gives proper data, he/she is given a specially generated number, the so-called token, which is assigned to the current login session. This token is used as the authorisation in all methods of net service, which is the only communication layer between the client and the server. Because the token is used, the login name and password do not need to be sent at each query to the net service. This improves security by reducing transition of sensitive user data to the minimum.

Having a token lifetime counter provides an additional security layer. Each token has been allocated a life span, which is incremented at each reference to the server. If the time allocated to the token for referring to the system is used up, the token's validity is barred and subsequent access attempts will return an error and redirect the user to the login page. Because of this solution, a token captured on a victim's computer cannot be used on any other computer in a different session.

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Because *E-matura* is not an open system, it was possible to add an additional security layer. The registration process begins from the recruiter, who contacts the unit representative, who wants to have the account in the system. This is via personal or telephone contact. Later, the interested person receives a paper form - an application for participation in the programme. By using the traditional verification method at this stage, all persons who want access to the account just to penetrate it have had been eliminated. After the verification of sent data, the interested person receives information, which is required to log into the system. This information is sent to the person by e-mail. The person who receives such an account is then authorised to set up such accounts for the users within his/her unit.

AUTOMATION OF BUREACRATIC PAPERWORK

Conducting the examination for the secondary school certificate is not just an encounter with technological challenges. It is also required to fulfil many formal requirements connected with the storage of personal data in paper form, which must be signed by every examination participant. Without proper authorisation, tens of thousands of students' questionnaires with personal data would need to be supplied to the central registry and manually entered into the system. It would take an enormous amount of time and generate many errors. To avoid such a situation, an automatic management system has been developed.

The teacher, who is responsible for the entering information about students, enters all this information into the system using an administrative module, which is prepared especially for him or her. Next, he/she prints a student card for each student, which must be signed. The key element for this system is the barcode on each card. This solution means that every card has been allocated unique barcode, so that each student can be clearly identified. The cards are scanned by a barcode reader by the central registry, and students' data are marked in the system as verified data.

These data have a paper equivalent with participants' signatures. This solution drastically reduces the amount of work related to the registration of students. Additionally, the number of potential mistakes is also reduced because data are verified while they are entered into the system. Therefore, there are no errors that could be associated with this process.

ELECTRONIC TEST ADAPTATION TO THE PAPER VERSION OF MATRICULATION EXAMIMATIONS

Each examination for the secondary school certificate must meet the requirements of the Central Examination Board. The immense challenge was to analyse and edit questions in such a way that they could be displayed in electronic form and checked automatically on the server. With the help of a friendly institution, which specialises in mathematics and hires people with considerable examination experience, it was possible to achieve mathematics at a basic level, with 95% coverage, which is a very good result according to numerous specialists. Thus, it was possible to overcome barriers with innovative solutions. Such barriers include people for whom the paper and pencil are the only option for taking the examination for the secondary school certificate. Because of good coverage in terms of the content questions of the paper examination for the secondary school certificate and a positive response from students and teachers, an increasing number of people are inclined to attend to an electronic form of examination.

POSSIBILITIES AND CHALLENGES

The *E-matura* system is designed and built to cope with heavy loads, which are generated by the huge number of students who sit for the examination simultaneously. The aim is to prepare the system for the future in order to replace the traditional, trial examination for secondary school certificate with this electronic system. The objective is to apply this system not only to mathematics but also to other examination subjects. The examination for the secondary school certificate, which is conducted electronically, has very high prevalence in comparison to the traditional one, mainly because the costs are lower.

Further, there is no need to employ a large number of examiners to check students' examination results, because the system automatically checks the whole examination and displays the results. There are also no printing costs, which has a very positive impact on the environment. In addition, security is increased because there is no possibility of someone seeing questions before the examination, as was the case when sending and distributing paper-based examinations to carry out traditional examinations for the secondary school certificate.

E-matura is connected not only with savings but also with the possibility of a better analysis of the examination process. Traditional examinations do not provide much feedback, except for student results from each task. The *E-matura* system collects a vast amount of information during the examination such as: the number of attempts at each task and the total time spent on each question or every change of answer. Collecting such data provides the examiners with many options because they would be able to see all the questions that caused students the most problems. Based on this knowledge, examination questions can be better adapted.

The examination for the secondary school certificate, because it is one of the most important examinations in the life of every student, should be conducted in such a way as to make it difficult to cheat. In Poland, this is a fairly big problem, mainly the result of the Polish mentality. The aim is to conduct the examination in such a way as to make it difficult for students to cheat. In the case of conducting the examination in the traditional way, where each student gets the same

examination paper, the prevention of cheating is based only on students being watched by examination supervisors. In the case of the examination for secondary school certificate performed using the *E-matura* system, options for preventing cheating are improved.

Nevertheless, examinations carried out with use of the *E-matura* system have many similarities with the traditional examination for the secondary school certificate. The examination is also administered in schools, where students take an examination at the same hour. Order in the class is also maintained by examination supervisors, but instead of using examination papers, students sit in front of computers and answer the examination questions on the computer screen. Students have to log in using their unique login name and password before joining the examination.

What is more, after logging into the system, students enter login names of students sitting close to them. Therefore, the system knows from whom this student could potentially try to copy the results. In addition, not only is it possible to analyse the similarities between students' answers, it is also possible to have the questions and the sequence of answers in a different order.

Cheating is, therefore, more difficult because although the numbers of questions might be the same, the content could be different. It means that even if a student could see the answer of his/her colleague to the question of the same number, he or she will not gain anything because the question might be about a different matter. The only way cheating would be possible is if the other student dictated all the content of question. However, chance of being caught by the supervisors is high. Generally, students are afraid to take such a risk, hence, this system and the solutions applied, discourage them from cheating.

The final protection against cheating would be to place cameras in every examination room to transmit and record vision during the examination. These pictures would be helpful in resolving doubts concerning whether students were cheating or not, and would also oblige and motivate a better examination.

CONCLUSIONS

E-matura is an evolutionary project, which is constantly being upgraded with new functionalities to overcome any new requirements and challenges. This system offers great opportunities in many respects, and has considerable advantage over traditional examinations. One such advantage is gaining results immediately after the examination so students do not have to be under stress awaiting results for a long time. What is even more important is that the analysis of a huge amount of data collected during every examination for the secondary school certificate conducted with the aid of the *E-matura* system, makes it possible to design better examination questions, which are better tailored to the knowledge delivered.

The *E-matura* system still faces many problems and challenges but this approach to the examination provides many opportunities that should not be missed. This is why the system is being constantly adapted and improved. Additional examination questions from other subjects are being added to this system, hence, it is envisaged that examinations for the secondary school certificate in Poland may soon be conducted only using the *E-matura* system.

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