Solved Problems of Electromagnetics as Educational Material on the Web: Development, Interest of Students and Future Approaches

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Abstract *— Web-based learning tools are indispensable in modern teaching, especially when the ability to reveal extra information on demand is an excellent tool for stimulating and engaging students. The complexity of problems from the field of Electromagnetics makes understanding and study difficult for students. Visualization of phenomena, animations synchronized with corresponding derivation of equations, sound and other multimedia elements allow students to better understand the topics and to gain some practical experience even without accomplishment laboratory experiments. The department of Electromagnetics at the Faculty of Electrical Engineering, University of Ljubljana, Slovenia, offered its first educational contents from the course in Fundamentals of Electromagnetics over the Web in 1998, and has since been actively involved in its maintenance and improvement. Our digital library includes approximately 1000 solved problems and is permanently growing. The evaluation of website access, carried out by analyzing the web server log files, revealed a great and still increasing interest for this educational material among Slovenian students. Explored students' navigational behavior will be used to identify their interests, enhance the quality and facilitate delivery of information services, and improve the server's performance. Our experience is based on several attempts to publish technical sketches and mathematical notations from the field of Electromagnetics on the Web. At the beginning, solved problems were published using static HTML and GIF images. At the end of 1999, when the Web site was also restructured into a portal, the Acrobat PDF format has been used for publishing similar contents. Previously described student interest motivated us to search for new approach for publishing chapters and this way extend the educational process by using animation synchronized by corresponding equations, sound and other multimedia elements using state-of-the-art technologies. We would like to share our experience with developing dynamic interactive multimedia educational material with integrated mathematical notation, because we believe such an application is not limited to the field of Electromagnetics and could be useful in other fields of science and technology.*

Index Terms *— Education, Electromagnetics, Equations, Mathematical Notations, Number of Hits, Solved Problems, Technical Sketches, World Wide Web.*

INTRODUCTION

Web-based learning tools have proved to be indispensable in nowadays education, especially since exists the possibility to reveal extra information on demand, which is an excellent way to stimulate students exists. Visualization of a certain phenomena, animations synchronized with corresponding derivation of equations, sound and other multimedia elements allow students to understand the topics better and gain some practical experience without performing laboratory experiments.

Our experiences are based on several attempts to publish technical sketches and mathematical notations from the field of Electromagnetics on the Web. In 1997, we started publishing solved problems using static HTML and GIF images, but since the end of 1999, when the Web site was also restructured into a portal, the Acrobat PDF format has been used for publishing similar contents. These two approaches as well as their advantages and disadvantages are presented in the beginning of the second chapter. Our digital library includes approximately 900 solved problems and is permanently growing with 100 – 150 additional problems per year.

The evaluation of Website access was made in two different ways. Firstly, a survey was carried out among students to find out their opinion. Secondly, Web server log files were analyzed and they revealed a great and constantly increasing interest for this educational material among Slovenian students. The results are presented in the third chapter which is also the main part of this paper. The explored students' navigational behavior and their opinions will be used to identify their interests, enhance the quality and facilitate delivery of information services, and also improve the server's performance. Surprisingly high percentage of students claim that they use the system very frequently in order to study for an exam. Most of

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them would like to use a similar system at other courses at the faculty and would appreciate the problems to be solved in a more detailed and structured way. Due presented students' interests we decided to look for new approaches for publishing the chapters and extending the educational process by using animation synchronized with corresponding equations, sound and other multimedia elements.

At the end, future work is outlined.

DEVELOPMENT OF THE PRESENT PORTAL SYSTEM

We started with publishing solved problems from the field of electromagnetics on the web in 1997. At that time, there was no support for presenting Greek letters, mathematical symbols or equations built in browsers. This lack of appropriate approaches for publishing natural sciences' contents forced us to search for more satisfactory ones. Further development and appearance of modern and more efficient tools for publishing and reviewing the web sites with mathematical equations and technical figures lead us to change the way of publishing. Another reason for changing the way of publishing problems during the first five years, was the possibility of faster access to the internet and faster computers. Because of that, new technologies could have been used to provide fast downloading of even more complex contents. However, each of those approaches has advantages and also some disadvantages, described below.

Approaches used for publishing sketches integrated with mathematical notations

The earliest and the simplest approach was using native HTML capabilities for a combination of text, symbols, fonts, tables and style sheet for more elementary material and black and white GIF pictures for technical sketches, diagrams and mathematical notations. An example of preparing this kind of education material is shown in Figure 1. The approach placed almost no burden on the reader to obtain additional software, such as browser plugins. Since only pure HTML was used, the system could be used on all the versions of web browsers and operating systems. The size of the contents was small which enabled a quick downloading. There are several drawbacks of this approach in practice. Equations and pictures do not display the same on all computers and in all browsers. The size of notations depends on the resolution of the screen and is therefore bigger when the resolution is low and the other way around. The user cannot influence on the size which is going to be presented. Content, prepared in this way does not encourage the authors to include dynamic elements. The mathematical notations published as images cannot be reused for further mathematical calculations, plotting or simulations.

We wanted to find simpler methodology for creating and publishing solved problems which lead us to search for a different approach. The most simple solution was to publish the material in a format that supports mathematical notions and provides the integration of the pictures. In 1998 it became obvious that the Adobe Acrobat Reader had become universal standard for publishing scientific materials. Adobe offers various tools which provide a simple saving or printing of the content into the PDF file. The file created in this way is a precise copy of the original document, which can be prepared in Microsoft Word, TEX, Mathematica, MathCad, etc. The author has therefore a total control over the formatting. The simplicity of the publishing the content is thus one of the reasons which motivated us to change the approach. Another reason was a very good quality and accurate printing of the PDF files that user can produce. An example of the procedure used for preparing this kind of education material is shown in Figure 2. The use of PDF documents also has some disadvantages. The files are bigger so they transfer slower over internet to the user. They require good screen's resolution in order to preview the documents in full-screen mode. PDF format requires from the user to have a software (plug-in) installed in order to display the documents and to superficially integrate them into the rest of the Web. Unfortunately, this approach also offers no possibility to reuse published mathematical notations for further mathematical calculations, plotting or simulations.

Administrative part for content developers

The administrative part provides uploading the documents to the web. At the beginning, solved examples were put on the web manually. This simplicity of creating PDF documents encouraged us to restructure our page into a portal and enable automatic contents distribution. Portal is built as 2-tier client-server application. The system architecture is shown in Figure 3. It uses SQL database at the server side. The date, label of problem, its metadata, the data about the author and file path are stored into the database. The PDF documents are stored into server's file system.

The content developer is supposed to describe the solved problem and point to the PDF document stored locally to transfer it to the server using interface shown in Figure 4. From that moment on a new link is added to the menu with the list of problems. Administrative part can only be used by privileged users that must enter a password.

User's part for students

The published solved problems are integrated in the Fundamentals of electrotehnics home page, available at http://torina.fe.uni-lj.si/oe. The problems can be listed by the date of creation starting with the newest one and followed by the one with previous date. The new approach will arrange the explained problems according to the field they belong to. A

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click on the link with the data of the exam opens a new windows and a solved problem appears using HTML with pictures or a PDF document. The user has an option to print a document or to close the window. User interface is shown in Figure 5.

SYSTEM USAGE EVALUATION

During 6 years of usage, students frequently expressed their opinion about the system. However, in January 2003 we did detailed inquiry about the system usage. It was performed by using two different approaches: we carried out a survey among students and at the same time we analyzed the web server log files.

Survey among students

The students who participated in our survey were asked to describe the process of working with the system, about its usefulness, the purpose of usage and about the way in which they are using it. The number of participants in a survey was 280 students. All students except one knew about the collection of the solved problems on the web. The majority (75%) of them were told about it by their teacher, 20% by their colleagues, and - surprisingly – 5% of the students claimed to found the collection via searchers such as Google or Yahoo!.

15% of the students affirmed that they look through all available solved problems while learning. The majority uses the collection of problems to rehearse before the exams, 15% claims that the collection of problems is their primal resource for learning for the exam. 20% of the students read the problems directly from the screen, while 80% print the problems. 10% of students print them also for their colleagues. 70% of them use the system at home others use it at the faculty (23%) or somewhere else. We were surprised by the fact that 55% of the users still have an access with an analogue modem at home. The rest of them are using new technologies (ISDN (15%), ADSL (15%), cable modem (10%)). The great majority of students find the system useful and would like to have the same kind of collection available at other courses as well. A very small number of students have found mistakes in the solution of problems. Most of the comments were very good and encouraging. Still, some students would like the problems to be solved in more detailed and structured way.

Website access evaluation

The Website access evaluation was conducted by analyzing the web server log files. They provide a great opportunity to learn more about the behavior of visitors to our portal and provide us with the information about how many times do users come, which problems do the review, how many times are distinct problems reviewed, how is the usage distributed over the year, etc.

For the website evaluation we used *WebTrends Log Analyzer*, which generates several predefined reports. The reports show the number of visits, transferred bytes, most frequently used pages, etc.

In addition to the reports mentioned above, we wanted to be able to perform interactive exploration, ad-hoc analysis and to discover trends in user friendly way. Because of that, we decided to use *Microsoft Log Parser* – a versatile tool that can be used to perform data mining and sequence analysis to discover user navigation paths both within a single session and across different sessions by the same user.

Access analysis was conducted for the year 2002. It revealed 187220 accesses during this period. The number of accesses in December 2002 has increased for 25% from December 2001, as shown in Graph 1. The peak day access was reached on 10 June (2351). The month distribution of request count shows, that interest is increased during the exam periods in January, April, June, September and December while the lowest interests for the study material is during the student's holidays.

The findings of analysis presented above takes aim at improving the web site content restructuring to enhance the quality and delivery of study material. It also identifies students' interests and can be used to tune server's performance.

FUTURE WORK AND CONCLUSIONS

The main disadvantages of the above described approaches are the static and inability of interaction, which are the main benefits of modern web educational contents. Visualization of phenomena to explain conditions and relations governing electromagnetic fields in the space done by utilization of physical and mathematical relations, drawing of field lines, tubes of flux and equipotential's in 2D or even in 3D animations is of a great help. These animations must dynamically interact with corresponding derivation of equations, supported with clear and concise explaining procedures. Users also expressed the desire to reuse published notions being met with in this area for further computation.

There are several different ready-developed technologies which can be used to accomplish elements that are readily available and therefore it would be irrational to start developing a new approach from scratch. Proprietary approach would require a user to have additional software (plug-ins) installed. Having limited financial and human resources, we will try to develop new approach, governing readily available state-of-the-art technologies: Macromedia Flash for animations and

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Design Science WebEQ with MathPlayer for mathematical notations. In order to establish their intercommunication and synchronization, browser scripting will be used.

Another advantage this new approach will be the possibility to reuse solved problems in programs which are supporting MathML (Mathematica, MathCAD). It will be possible to copy the equations directly from the web to the mathematical program to modify them or to make further calculations. This should encourage the student to deep into the problem more seriously.

We expect these step-by-step solved and animated problems to enrich the presented databank of problems and to become an indispensable educational material among the classical student books, printed collections of solved problems and laboratory experiments.

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FIGURES AND TABLES

FIGURE 1
THE PROCESS OF PREPARING EDUCATION MATERIAL IN HTML + GIF FORMAT

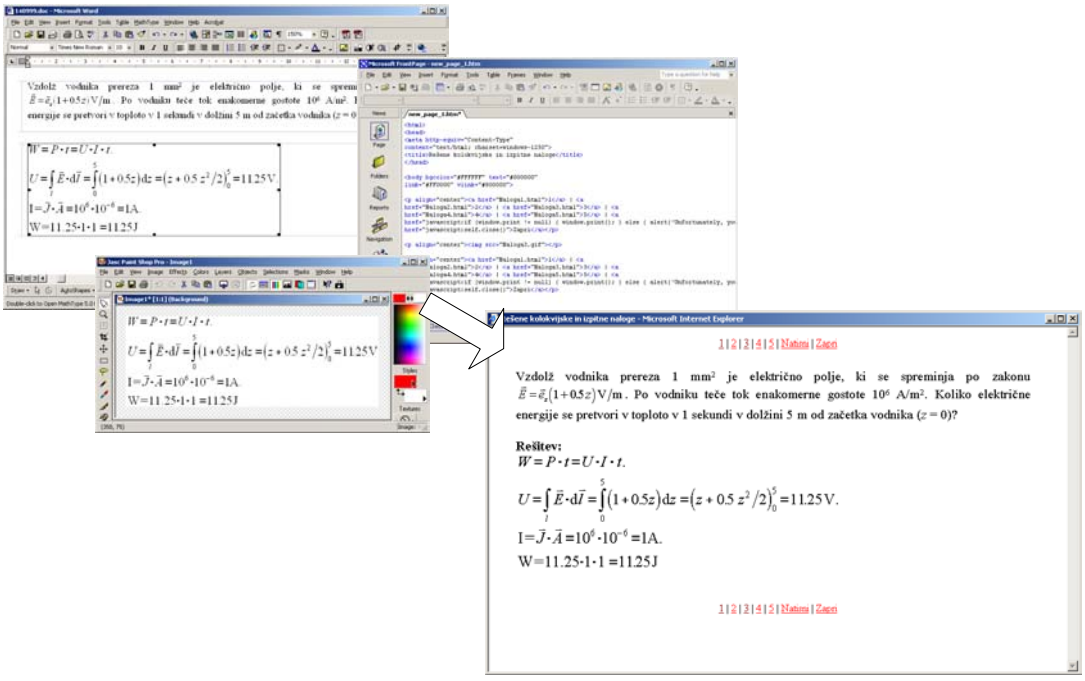

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FIGURE 2
THE PROCESS OF PREPARING EDUCATION MATERIAL IN PDF FORMAT

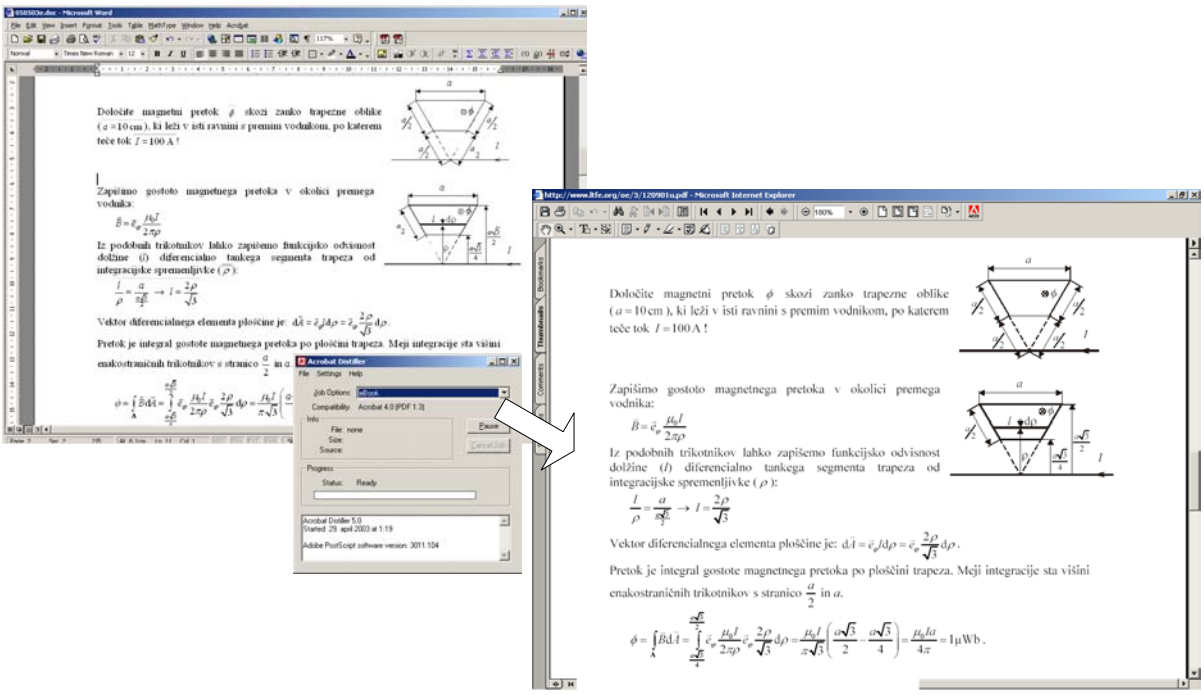

FIGURE 3
THE SYSTEM ARCHITECTURE

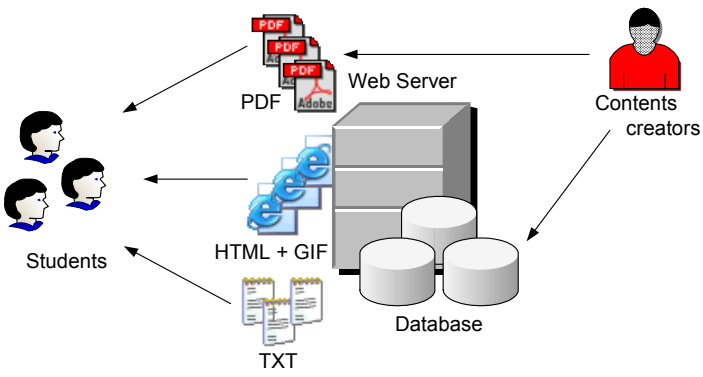

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FIGURE 4
THE PROCEDURE FOR PUBLISHING PDF FILES

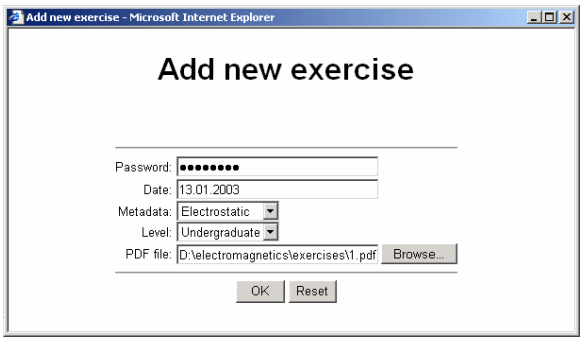
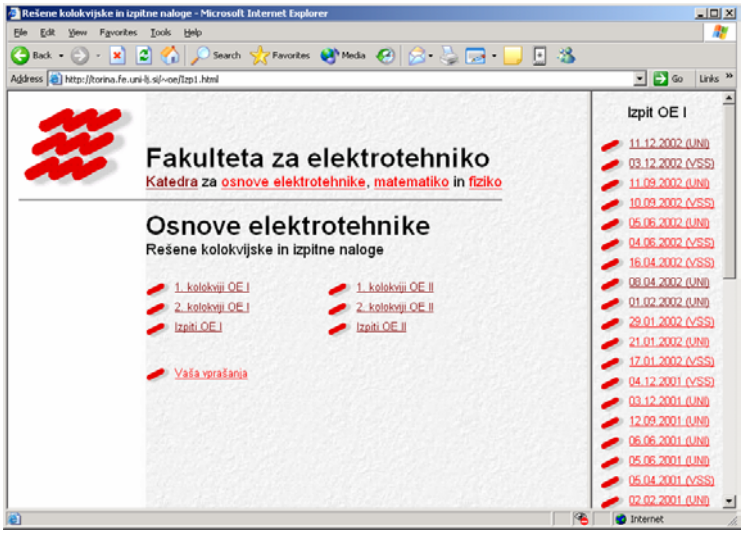
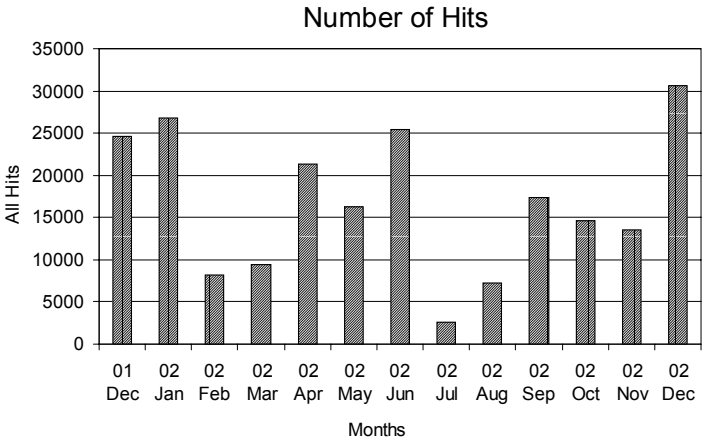


FIGURE 5
LIST OF PROBLEMS ORDERED BY DATE



GRAPH 1
THE DISTRIBUTION OF THE REQUEST COUNT



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