

A Modern Way of Teaching Electrodynamics

Abstract— Recently, traditional lectures on fundamentals or theory in electrical engineering have suffered significant abridgements concerning the credits awarded for successfully passing these courses. For this reason, new means of knowledge transfer need to be developed in order to motivate students to invest time for familiarizing with essential contents which can no way be shortened equivalently to the credits for keeping engineering education on a high level.

Hence, one of the most important steps to support students' efforts is to re-design lecture notes and textbooks in a structured, highly efficient way, including interactive content and media.

In order to counteract against unnecessary amounts of additional work load resulting from updating and publishing various courseware versions, tools for improving document creation and conversion have been developed and are now being applied for the first time on a new "Electrodynamics" - courseware.

Index Terms— eLearning, Web Based Training, Multimedia Teaching, Electrodynamics.

I. MOTIVATION

Studying electrical engineering in 2003 at Graz University of Technology (TUGraz) is significantly different from doing so several decades ago. Many new subjects coming e.g. from the huge areas of information technology or from computer science have to be covered and soft skills have become part of the curriculum. At the same time, the total number of credits necessary to get ones bachelor or master degree has decreased distinctly. Since these two objectives are conflicting each other, a common solution is to reduce the volume of some of the classical topics of electrical engineering, mathematics and/or physics.

Unfortunately, one of the first areas to be cut short is the one of electromagnetic field theory. Maybe this is acceptable for one or the other specialized curriculum, but as soon as a student or an engineer has to deal with basic physical phenomena, their origin and effects, she or he will notice a remarkable deficiency in knowledge. Computing capacitances in integrated circuits or designing contact free systems for charging toll on motorways, the list of tasks where a profound knowledge of electrodynamics is essential could be continued arbitrarily. But instead of complaining about this even worsening situation, it is necessary to attract the students' (and maybe also) our colleagues' attention (and appreciation) by brushing up our lectures and bringing them into a modern form.

In 2001, a project for developing new ways in education and teaching called "Multimediale Lehre [Multimedia Teaching] - Web Based Training" MML/WBT was founded at TUGraz. One of the first packages of courseware to be published was dealing with contents of Fundamentals of

Electric Circuits, technically building up on [1]. Students were then forced to learn the first few chapters on-line only, followed by traditional lectures. Surprisingly, evaluation of the course brought quite conflicting results.

First it has shown that lecture notes printed on paper are no way out of date, despite the fact that most of the students asked were familiar with internet usage and have already tried to learn by using computers. A 'real' textbook was much more convenient for learning mathematical contexts as well as basics and fundamentals of electrical engineering.

Anyway, the offer of electronic courseware was highly appreciated, and most of the evaluation participants found the interactive parts in general and the so-called "virtual experiments" and "virtual labs" in particular very useful. In addition, new communication channels provided by the WBT framework were used quite frequently. That means in a synthesis, that learning basics and theory is better done by using a paper script, but when it comes to training for applying this knowledge, computer and internet seem to be the better tools.

When striving to attract the students for these new ways in teaching, it is essentially important to exploit as many learning channels as anyhow possible. Luckily, today's computer and network systems offer plenty of opportunity to serve in this manner by supporting various ways of content presentation, usually referred to as multimedia. For easy course updating, in-time communication and simplified distribution management, a client-server solution seems to fit best for offering e-courseware. Unfortunately, serving a distributed number of students with rich multimedia content requires a certain amount of bandwidth - on both ends of the line. Waiting for server response in times of high load are no benefit in this context, too, which in combination could result in sluggish operation and thus being regarded as inconvenient from the users point of view. Offering offline courseware does not cause these troubles, but authors need to have well in mind that the nature of this technology turns down communication at the same time. There is now a need for three different versions of course-ware:

- off-line, paper-based
- off-line, electronically, CD-based
- on-line, electronically, web-based

Assuming that the content remains the same, not depending on the way of representation, full-featured courseware creation for all three media would result in having to essentially do three-times the same work. One can argue, a solution could be to create documents in some data exchange format that keeps layout and design both printed and in online or offline electronic form. PDF [2], for example, would be

such a format, but as being a "what you see is what you get" representation of an imaginary paper page, it is too static for carrying multimedia material.

Taking into account the prerequisites of being as platform independent as anyhow possible while not having to rely on proprietary data structures, HTML is today's format of choice. Combined with JavaScript, Java or some more specific browser plug-ins (e.g. for in-line video-clip presentation), courseware written using this language quite closely meets multimedia demands. In addition to the fact that they can be displayed both on-line and from off-line storage media such as CD-ROM, HTML pages offer the benefit of seamless inclusion into modern e-learning platforms. Deciding to make use of servers implementing such platforms gives access to a number of features unknown from traditional lectures and off-line learning as well. The next section will give a comprehensive overview over the system used at TUGraz.

II. GOING ON-LINE: THE ELS ENVIRONMENT

Comparing off-line versions of multimedia courseware with those prepared for on-line access, one can spot plenty of misfits. Once created and distributed, changes of content are expensive and ineffective in a way that makes it very difficult or nearly impossible to maintain fast-changing course topics appropriately. In addition, modern forms of communication provided by the Web cannot be used, while exactly these means of knowledge transfer is so highly valuable and distinguish electronic courses from traditional, paper-based ones.

For that reason, Learning and Content Management Systems (LCMS) are being used for covering these problems and for handling the surrounding demands on 'real' e-Learning platforms.

Fully functional platforms provide five different areas of work:

- Presentation of content
- Communication tools
- Tools for creating exercises, assessments and tests
- Administration
- Evaluation of courses and grading of students' performance

At TUGraz, the combination of the University's management system TUGonline [3] and HyperWave's electronic Learning Suite eLS [4] as WBT platform fulfills all five needs.

A. Presentation of Content

The e-Learning Suite primarily works as a web server, presenting html pages with all possibilities concerning hypertext and its multimedia inclusion features. This means consequently, publishing plain text, graphics and images is of no problem at all, and other forms of media aren't either, as soon as appropriate plug-ins are installed on the client's side. Anyway, a sophisticated e-Learning System offers a

wide-spread variety of advantages in comparison to normal web servers:

- It handles the administration of students' learning progress and compiles a set of statistics on it
- Annotations to pages already published can be set from both trainers and trainees - if necessary these annotations can be held privately -without touching the source html code
- Course selection, tables of contents and courseware digests are created dynamically out of the published content and therefore do not need to be revised by the author after each change

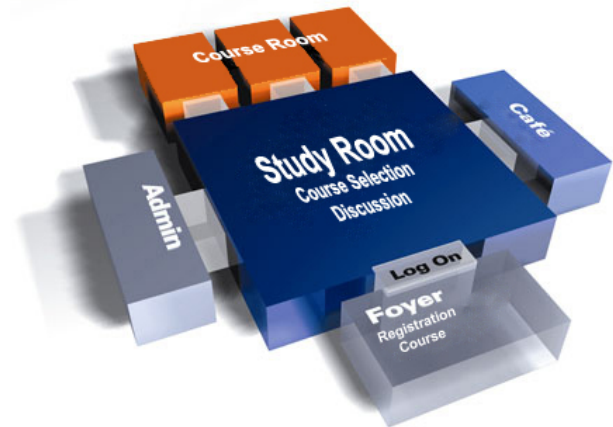


Fig. 1. eLearning Suite - configuration structure

B. Communication Tools

Within eLS, the interactions between teachers and students as well as among students get a fully new dimension, unknown from common lectures. Because being closely related to the form of conversation known from real life, the talks held in the virtual Café encourage students to discuss lesson matter synchronously by additionally providing others with the possibility to find answers to frequent problems by just observing the discussion. Trainers or authors may offer some time usually allocated for office hours on virtual consultation hours, and so, on the other hand, give the opportunity to get professional help on certain topics. While synchronous communication has the advantage of being independent of the participants' location, means of asynchronous communication don't even require predefined time slots. eLS implements these channels with an info-board and newsletters, additionally course subscribers can put questions and annotations directly into the course pages and answers may follow consecutively. This feature induces discussions on content 'right on the spot' where problems occur. Latterly, even some internal e-mail distribution system (WBTmail) has been implemented, enabling even personal, non-synchronous communication.

C. Tools for Creating Exercises, Assessments and Tests

On the whole, there are three forms of electronic exercises known.

Assessment by programs:

Simple drill of basic knowledge. The answers are evaluated by a program; the most common forms of these exercises are right/wrong questions, multiple-choice-tests, fill-in texts and many more. JavaScript does the work here within html courses. At TUGraz, a number of tools already exist for simple test creation [6]. These exercises are also well suited for self-assessment by students, so that they can discerningly visualize their learning and study progress.

Assessment by professionals:

Exercises leading to more complex answers are difficult to evaluate by programs. Here it is possible to hand in the results by mail, after which it is the teacher's work to analyse them. In this stage, there is no additional value to traditional homework, but the presented results can be offered as teaching aids again, which can easily be done within eLS as changed content is being published immediately. eLS offers a sophisticated interface for such processes, which is capable of the overall management such as workgroup, deadline, and hand-in administration or upload server control. Additionally, the collection of results being uploaded may, if intended by the trainer, be published immediately after hand-in deadline so that every enrolled student has the possibility to compare his creations to others.

Self-Assessment:

When the results of such an exercise are evaluated by the students or the group of conducting students themselves and then compared to (one of) the model examples, one talks about self-assessment. Instant, convenient result publishing management serves for this purpose, too. Discussion and comments by other students or the teacher then help to find out whether the own results fit to the suggested solution. Discussion channels for this purpose are provided by eLS in a broad variety.

D. Administration

At TUGraz, the administration of students, their subscription of different (real-world) courses, of examination dates and students participation and grading, of course evaluation and much more is supported by the applications provided by TUGonline [3]. Every new student is assigned a virtual identity in this system after registration, and since the new version of eLS [5] is now capable of communicating with the databases of TUGonline, this is greatly simplifying subscribers identification, startup authentication and course evaluation processes.

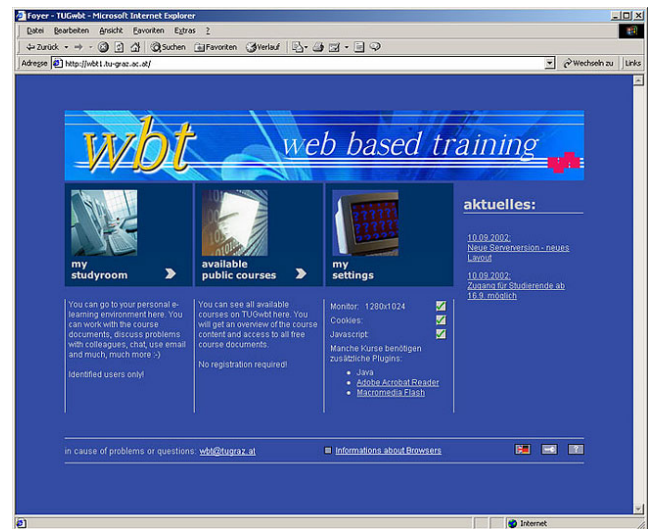


Fig. 2. WBT "Foyer" of eLS

E. Evaluation of Courses and Grading of Students' Performance

As it is the case in traditional lectures, students should have the opportunity to evaluate subscribed courses on-line in order to give feedback to the teachers and to express improvement suggestions or criticisms. As there a nexus between learning and administration platforms exists, this possibility is open to online courses too. The same applies to student grading examination results are being gathered by the TUGonline system and recorded for utilization by students or other institutions at the university.

III. COURSEWARE PRODUCTION

The need for three - from the technical point of view - different forms of content presentation forces courseware authors to make use of certain tools to produce the best results possible for each of the three versions.

\LaTeX is still the system of choice for word processing as it meets most layout standards. Furthermore, \TeX scripts are easy to parse because of their logical structure which makes it not too difficult to build converters from \LaTeX into another scripting language. Hence, \TeX scripts form the source code for both paper-based courseware and electronic courseware.

Unfortunately, direct \LaTeX products such as DVI or PDF lack interactivity and multimedia demands, whereas HTML with certain plugins, if necessary, supported by Java and JavaScript is capable of handling complex multimedia content. This incompatibility would cause three times the same work for creation and changing of documents if no ways for automated courseware production can be found.

A compromise is now to have \TeX scripts converted to HTML and to enrich the results with as many interactive

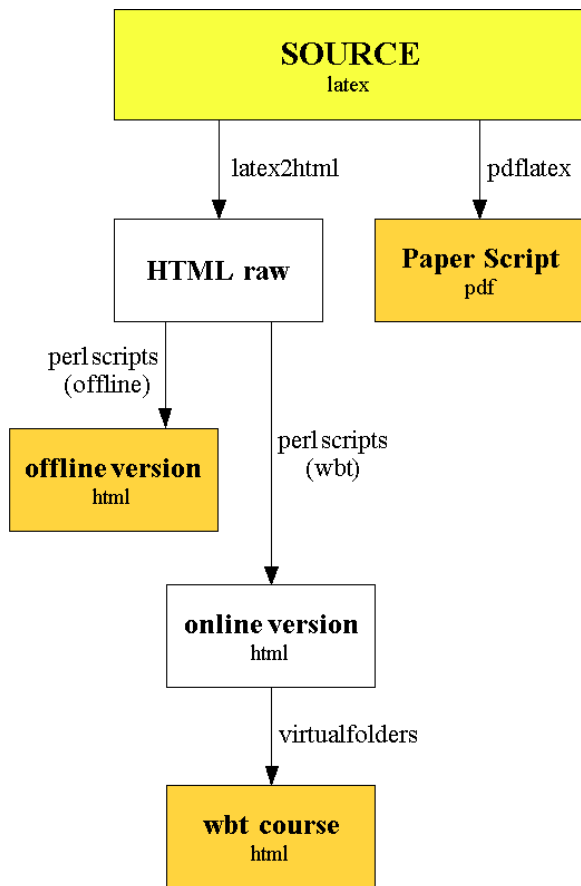


Fig. 3. Procedure of Courseware Production

content as possible and/or necessary, but force the compilation to DVI to ignore these multimedia parts. Certain commands, defined in a special \LaTeX style file, give authors the opportunity to distinguish between parts suggested for being printed on paper, and those that should appear only in the electronic versions. Even raw HTML code can be entered here, without being touched during the conversion process. This is particularly useful for integration of Java Applets, Flash animations [7], virtual laboratories, interactive examples and video or audio clips.

latex2html2002 [9] performs the necessary conversion quite conveniently. It is a freeware bundle, using customizable PERL scripts [8] to split large \LaTeX files into shorter, more user-friendly HTML pages, to perform all necessary conversions and formatings, and - very important within a scientific environment - to automatically take 'screenshots' of formulas and special characters HTML is (still) not capable of representing. Controlled by certain optional commands, the conversion software already provides useful results, although the pages still contain some major faults and hence need to be touched up. Some additional PERL scripts work now on the newly generated files:

- *Copying the files into the right order*
Here, all image files are put into a special directory

right at the root of the output file tree. When producing cd-based courseware, all HTML files end up in the root directory, too, whereas for proper index creation within eLS it is necessary to sort the pages by their section marks which leads to a tree structure.

- *Repairing formula references*
latex2html2002 converts \LaTeX formula references into hyperlinks. When being clicked, the browser software simply follows these links and presents another part of the courseware, very often confusing the user and causing the 'Lost-in-Hyperspace' phenomenon. Therefore, a piece of JavaScript is inserted here, forcing the browser to open a new window of the size of the referenced formula containing only its image and number when a certain hyperlink is being clicked by the user.
- *Repairing figure integration commands*
As fine as the representation of converted formula images is, as poor it is for converted figures that have been included in the \TeX script. If an image is intended to be published electronically, too, it should be saved in .png or .jpg format additionally. This script then handles the proper integration of the correct image file and the change of references on figures as mentioned above for formulas.
- *Layout modification*
Now some minor changes in the HTML source code concerning special characters and page layout are being performed, a stylesheet [10] modified with information gathered by this script is being created.
- *Header and footer creation*
Here, headers and footers are inserted into the single pages, containing page numbering, a logo, and navigation facilities for the cd-based version. eLS has a built-in navigation system, therefore it is neither necessary nor practical to provide an additional one.
- *Index creation*
Again, eLS does this by itself, but for an offline version a table of contents would definitely come in handy. This script automatically creates one.

IV. DESIGNING A NEW COURSE: "ELECTRODYNAMICS"

Following one of IGTE's main topics of education, "Electrodynamics" is among the largest lectures offered on basics and theory of electrical engineering. Being part of the curricula Electrical Engineering and Telematics [3], after modernization of these curricula the lecture notes are now being re-authored, too. Replacing the loose collection of topics currently existing, a thoroughly styled, structured and layouted version is currently in development.

As an illustrative example, the topic "Multiconductors" will be used in the following sections.

Starting from a plain Latex source code (Fig. 4), pdflatex, latex2html and several subsequent PERL scripts produce as an output a well known PDF document (Fig. 5), an offline, CD-based HTML version with navigation bars, section numbers, linked references, etc (Fig. 7) and the course content to be inserted into the virtual learning environment eLS (online version, Fig. 6). The following images show the source code of the subsection "System of Linear Equations" within the "Multiconductor problems" and the three outputs produced from it. The following images show the source code of "System of Linear Equations", which is a subsection of "Multiconductor problems", and the three outputs produced from it.

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\section{System of Linear Equations}
\begin{equationarray}
Q_1=c_{11}V_1+c_{12}V_2+c_{13}V_3 \\
Q_2=c_{21}V_1+c_{22}V_2+c_{23}V_3 \\
Q_3=c_{31}V_1+c_{32}V_2+c_{33}V_3 \\
\label{eq:multiconductor_eq_1}
\end{equationarray}

where the  $c_{ij}$  are still to be determined.

In general, the  $Q_i$  become
\begin{equationarray}
Q_i=\sum_j c_{ij}V_j \quad j...number\ of\ electrodes
\end{equationarray}

The  $c_{ij}$  are termed coefficients of capacitance, the  $c_{ii}$  have a positive value, while  $c_{ij}$  ( $i \neq j$ ) are negative. Finally it can be shown that  $c_{ij}=-c_{ji}$ . Dealing with practical problems, it is more likely that voltages are available rather than potentials. This gives rise to the following modifications to (1.1).
\begin{equationarray}
Q_1=c_{11}V_1+c_{12}V_2-c_{12}V_1+c_{12}V_1+c_{13}V_3-c_{13}V_1+c_{13}V_1 \\
\end{equationarray}

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Fig. 4. latex source code for section "Multiconductor problems"

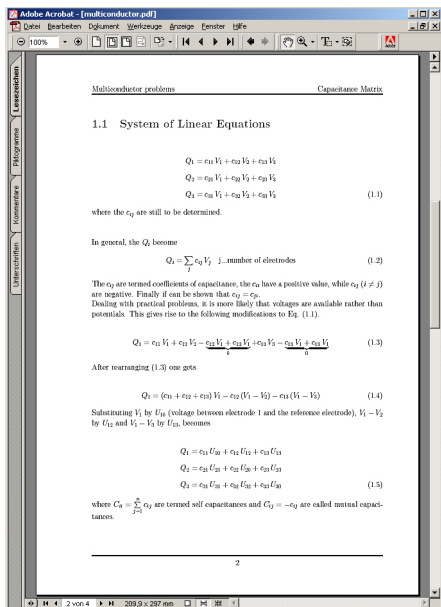


Fig. 5. pdf version of section "Multiconductor problems"

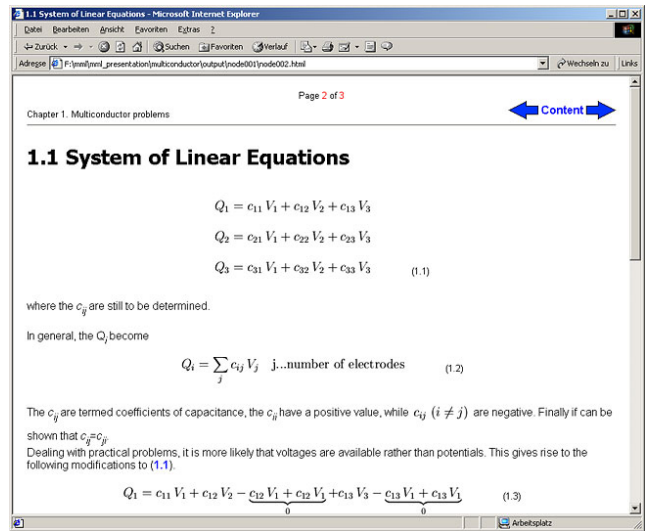


Fig. 6. offline version of section "Multiconductor problems"

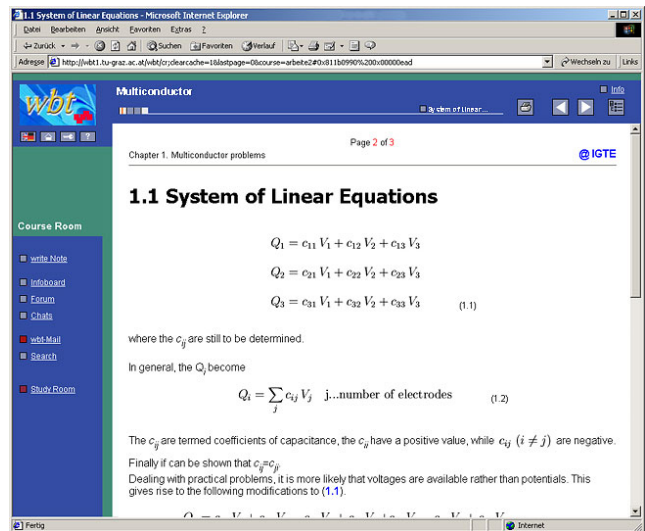


Fig. 7. online version of section "Multiconductor problems"

V. VIRTUAL LABORATORY

Interactive modules form the most important options CD-based and web-based courseware offer. By using this feature, it is possible to "train" previously accumulated knowledge. In the case under inspection, these "virtual laboratories" call some kind of software for the solution of the respective problem in a more or less transparent way.

As an example, for the course under investigation the programme package EleFAnT2D [11] was used as a back end.

After explaining with the help of a slide show (Fig. 8) how coefficients of self capacitances and mutual capacitances can be obtained by measurements (or simulated measurements) of charges (or charge densities), the student can virtually enter a prepared laboratory (Fig. 9). Consequently, it is possible to establish several electrodes either connected to a voltage source or to ground (Fig. 10). The

data of this "experimental" setup are then transferred to an EleFAnT2D solver, which is operating either online or offline, depending on the nature of courseware being distributed. The necessary results (charges stored on the electrodes or charge densities) and, if requested, some auxiliary results (field plots, ...) are send back to the user (Fig. 11). Now it is up to her/him to interpret the results and calculate whatever she/he needs.

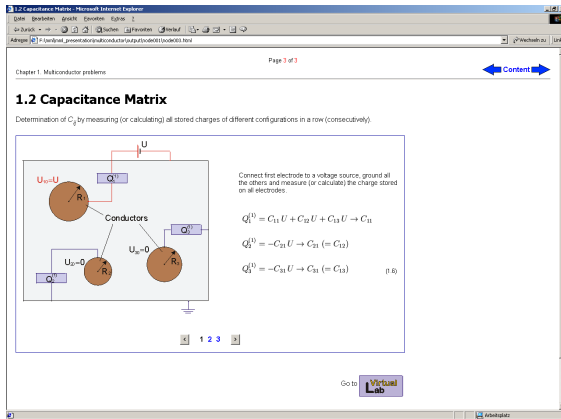


Fig. 8. Slide show: Determination of coefficients of capacitance'

VI. CONCLUSION AND PREVIEW

In the last few years, virtual and web-based courses have enjoyed more and more attention. Both courseware production and maintenance as well multimedia features creation is rather cumbersome, though. This article proposed the application of pdfLatex and latex2html, enhanced by a suite of Perl scripts to produce paper-, CD-, and Web-based lecture notes with the least efforts. For the latter cases, virtual laboratories have been suggested along other ways of exploiting computers multimedia capabilities. These means for training and consolidating accumulated knowledge are expected to raise students interest in quite theoretical topics, giving them a modern look&feel combined with useful, yet unknown functionality and convenience.

Following these claims, calling (commercial) software packages such EleFAnT2D in a server/client environment for gaining higher levels in usability and completing the suite of PERL scripts to tune and customize the raw html files will be part of the future work.

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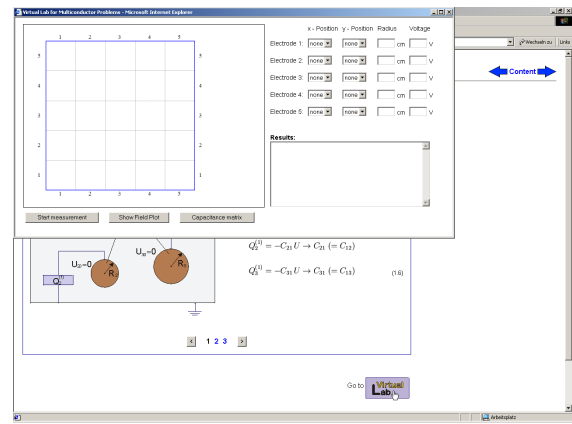


Fig. 9. Entering the virtual laboratory

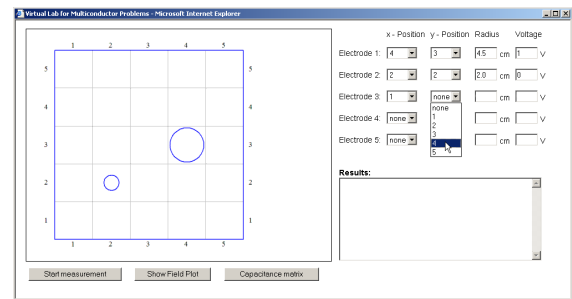


Fig. 10. Virtual Lab: Setting up the experiment

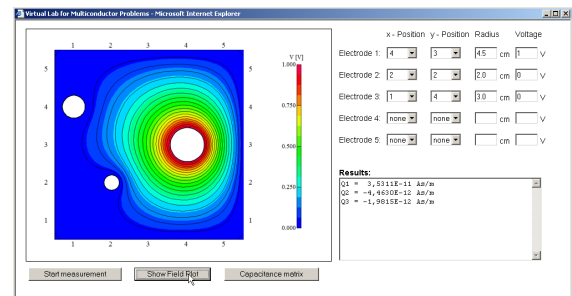


Fig. 11. Virtual Lab: Retrieving the required information

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- [8] <http://www.perl.com/>
- [9] <http://www-texdev.mpce.mq.edu.au/12h/docs/manual>
- [10] <http://www.w3.org/Style/CSS/>
- [11] Computer program package EleFAnT2D IGTE TUGraz, <http://www.igte.tugraz.at/>