Comparison between traditional and web-based interactive manuals for laboratory-based subjects

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This paper presents the salient features of web-based interactive manuals for laboratory-based subjects and compares them with traditional laboratory manuals. The manuals utilize the latest developments in web applications, JAVA programming and pre-designed spreadsheets with the objective of reducing the time taken for students to perform the mundane and laborious calculations and plotting of graphs. The students can therefore utilize the time in the laboratories on the analysis and discussion of results besides performing the actual experiments. Moreover, the web-based interactive manuals incorporate virtual experiments, digital pictures, animated GIF files and quick movies to familiarize the students with the experimental set-up before performing the physical experiments. The proposed approach is applicable for laboratory-based subjects, which are not amenable to be converted completely to virtual laboratories.

Key words: web-based applications, laboratory-based subjects, Java programming, virtual experiments

INTRODUCTION

Multimedia and web-based presentation of courses are becoming very popular with the proliferation of personal computers and the popularity of web-based applications. The materials can be accessed at any time from anywhere. This mode of presentation is being used regularly by academics for putting up web-sites for courses and non-experimental based subjects.

In recent years, many instructors have started to mount the description of the laboratory classes on the web. A typical web page usually only contains information on the schedule, objective, and a simple description of the laboratory assignment in the form of HTML files [1]. Some web-sites for laboratory classes also contain related programs and software required for the manipulation and computation of results. For example, the web-site for the subject of undergraduate laboratory [2] contains a list of MATLAB executable files.

For other engineering subjects [3], the handouts are presented in the form of PDF files using the software Adobe Acrobat. The material properties and data required for a particular experiment are presented in the form of HTML files. A video tour for one of the undergraduate laboratories [4] was also presented on the web. Other features include presentation of the use of some test equipment in the form of quick movies or short video clips. The students therefore will have some general idea of the use of typical test equipment before going into the laboratories. The department of Electrical and Computer Engineering, National University of Singapore has developed a web-based Remote Laboratory Experimentation [5], which enables electrical engineering students to control the real instrument through the internet and conduct oscilloscope experimentation remotely.

With the development of new computer technologies, JAVA (an interactive multimedia programming language), and the web application, some researchers have started to explore the possibility of simulating engineering and science laboratory projects on a computer. These web-based laboratory classes are offered via the web or CD-ROM and are known as virtual laboratories. The entire experiment is performed on a computer without the need to go to a physical laboratory. Experimental oriented problems can be offered without the overheads incurred for maintaining a full laboratory. The web-site of Johns Hopkins University [6] contains some of these virtual laboratories. Examples presented are on the subjects of diffusion processes, logic circuit, and robotic arm control, heat transfer in a duct and some other related topics. Another example of virtual laboratory called CyclePad has been field-tested in undergraduate engineering classes at Northwestern University, The U.S. Naval Academy and Oxford University. The web-site contains a virtual experiment related to thermodynamics [7]. It enables students to construct and analyse a wide variety of thermodynamic cycles.

All the web sites examined and mentioned can be accessed freely on the web. The author has not examined any other web sites, mainly because they have either restricted access, or access has to be purchased.

In summary, the web has been used for conducting laboratory classes in two different manners. On the one hand, it is used solely as a media for transmitting handouts and some relevant software and results, just like the use of the web for other non-laboratory based subjects. On the other hand, some researchers have completely done away with the need of setting up a physical laboratory and instead require the students to perform the experiment in a virtual environment. Of course, such an approach is controversial and may not be suitable for some engineering subjects that require the students to have some hands-on experience with the use of test equipment and machines. The present paper attempts to present an intermediate approach of using the web in an interactive manner for helping the student in putting up the laboratory report and to familiarize himself with the physical set-up and running of the equipment before performing the physical experiment. It is designed to enable the students to work in a more efficient manner so that they can spend more time in the class on the analysis of data they have just obtained. The suggested format retains most of the existing features for the running of a laboratory class.

TRADITIONAL FORMAT FOR LABORATORY-BASED CLASSES

Laboratory classes are usually part of a course on Science and Engineering subjects. The objective of laboratory classes is to reinforce the students' understanding of the fundamental concepts by observing, analysing and applying these concepts for some physical phenomena. Traditionally, laboratory classes are organized in the following formats. There could be some slight variation dependent on the schools and instructors.

(1)   Students are given a hand-out with the description of the laboratory before the actual session for performing the experiment. The students are expected to read the hand-out before the laboratory classes. An ideal situation is to cover the relevant topics in lectures before the laboratory classes. This may not be possible due to class size and difficulty in scheduling constrained by limited space, facilities and equipment. In a typical write-up downloaded from the web, the instruction to students is as follows:

> 'The most important thing that you can do to prepare yourself is to read the lab write-up prior to the class. You are not expected to be able to perform the laboratory from memory or to have total understanding of the lab exercise when you come into the laboratory. However, if you do read through the write-up before class, you will have an idea of what data information you are seeking. You will probably also have good ideas about the procedure necessary to acquire the data, even if it is not completely clear.'

A conscientious student will try to have a better understanding of the content of the laboratory by referring to textbooks or lecture notes before going to the laboratory classes.

(2)   During the laboratory classes, the instructor or teaching assistant will explain the main points of the experiment to be performed. He may also explain the use of equipment and demonstrate the whole process. Depending on the instructors and the experiments, the students may be required to bring floppy disks to the laboratory classes so that they can store the data for subsequent composition of laboratory report. The students are usually asked to record the data in a log book.

(3)   The students are expected to complete the experimental work within the time assigned and are usually encouraged to check the experimental results by at least preparing the experimental results in plots or figures in the class. However, if the final results require laborious computation of data obtained from the experiment, it may not be possible for the student to complete the plot within the time limit.

(4)   The students are usually required to submit either a short laboratory report or a long formal report within a fixed time frame. It could range from a day to several weeks depending on the instructors. With the proliferation of personal computers, the reports are usually required to be typewritten or more likely to be composed by word processing software. The graphs and plots are also expected to be drawn and prepared using graphical software. The content of the report is usually in the following format:

   (a)   Title page (or a cover sheet)
   (b)   Abstract
   (c)   Introduction
   (d)   Procedure
   (e)   Data/Calculations
   (f)   Observation/Discussion of results
   (g)   Conclusion
   (h)   References

It is usually impossible for the students to compose all of these within the time spent in the class. The students may be asked to complete some sessions of the report in the class, usually part (e) on the collation of data and calculation of results, before being allowed to continue composing the report outside the laboratory.

DRAWBACKS OF THE EXISTING FORMAT FOR LABORATORY CLASSES

(1)   Experiments are usually performed in small groups. Although the group partners are encouraged to discuss the materials during the laboratory sessions, each student is usually required to submit an individual report. Plagiarism becomes an inherent problem due to the following factors:

   (a)   The content of the experiment as well as the discussion and questions are the same for every group or student. The instructors are usually quite reluctant to change the content of the experiment or questions due to the extra effort and logistics involved for printing and distributing the handouts prior to the class as well as the extra time and efforts for setting up new experiments. This problem could be partially solved by posing different questions to different groups.

   (b)   It is usually impossible to complete the laboratory report within the time limit due to laborious calculation of results. The analysis and writing of discussion is usually done outside the laboratory. It is impossible to stop the students from collaborating with each other or their seniors in putting up the reports without the supervision of instructors or teaching assistants.

   (c)   With the proliferation of personal computers, plagiarism has taken a high-tech twist. The students only need to spend very minimal time in copying the work of someone else from the floppy disk or hard disk. Some students even put up model experimental reports on the web for everyone to download. The problem is usually aggravated by the common practice of using the same experimental set-up over the years. The instructors may try to solve this problem by imposing severe penalties for plagiarism.

(2)   The students usually spend the remaining time in class performing some laborious calculation and plotting of graphs and do not have sufficient time to analyse the data and results. The students are not prepared to discuss the results with the instructors or the teaching assistants during the laboratory classes. The role of the instructors and teaching assistant is thus reduced to just explaining and demonstrating the laboratory. There is no opportunity for meaningful discussion.

(3)   Students usually submit reports with unnecessary reproduction of text and materials in the laboratory handout with the intention of just filling in space for making a presentable report.

HOW THE WEB-BASED INTERACTIVE MANUAL COULD RESOLVE THE EXISTING DRAWBACKS

Preparation for the laboratory classes

Digital images of the actual test equipment and machines used in the experiment are included in a typical interactive laboratory manual. Detailed description on the use of these items could be presented in the form of HTML texts, animated GIF files, quick movies or short video clips. Students will be familiar with the use of these items before the class. The instructor or teaching assistant therefore need not spend too much time introducing or explaining the use of these items in the class.

There could be hyperlinks within the HTML files to various topics related to the scope of the laboratory work. The students can easily access the relevant lecture notes, which have been

posted on the web for terms and theories that they are not familiar with. The instructor or the teaching assistant need not sped too much time explaining these terms and theories.

Computation and presentation of results

The use of the web on this aspect of the laboratory work would be dependent on the objective of the experiment. For students performing an experiment related to engineering disciplines. The objective is usually not the ability to perform some laborious calculations or the use of least-square method for computing the best fit curves. The laboratory is usually designed for the student to have a better understanding of a physical phenomenon and not on the ability to perform some standard mathematical calculation or the plotting of graphs. JAVA programs or typical spreadsheets can be used to perform the laborious calculations and the plotting of the experimental data. An example was presented by Lee and Sabbir Ahmed [8]. JAVA programs can also be used to determine the best-fit lines or curves. The time required for performing such a task could therefore be drastically reduced. The students can easily obtain the graphical output immediately after they have collected all the data. They can thereafter analyse the results to check whether they have made any mistake. Some checks such as the checking of units and range of values with on-line helps can also be built into the program.

Discussion of results

As the manual is presented on the web, the content of the questions for each group and even individual student can be changed easily. JAVA programs can be used to generate random numbers for variables required for a certain computation for different groups or individual student. As the students need not spend too much time on the computation of results and presentation of data, they will be able to analyse the results in the class. The instructors or the teaching assistant can go around the class, checking and discuss the results of each student. The emphasis of the laboratory session could therefore be shifted from the calculation of results to analysis of results.

Submission of reports

The reports can be submitted electronically via the Internet if it is supported by a server. One can even explore the use of the computer to grade the report. If a more traditional approach is desired, the graph and table generated can be copied and transferred to word processing software for the preparation of the report. A hard copy can then be submitted in the usual manner.

EXAMPLES

The present project is prompted by the introduction of IVLE (Integrated Virtual Learning Environment) within the National University of Singapore. Many locations including classrooms, laboratories, canteen and dormitories within the campus have been fitted with UTP points for the students to access the university computer network. There is also a special scheme to offer financial assistance to students to acquire a notebook computer.

A web-based interactive manual for an experiment to demonstrate the principle of the conservation of angular momentum has been reported by Lee and Sabbir Ahmed [8]. Initial design includes digital pictures of the actual equipment and machines that are used in the experiment. After all the required information has been filled in, a JAVA applet will draw the least-square

line. It will also compute all the required information on the slope and intersect of the line and the system moment of inertia. Subsequently, a virtual lab for this experiment has been developed.

Besides the digital pictures, a pre-designed Excel spreadsheet has been included in another interactive web-based manual for an experiment on the behaviour of a spring-mass-damper system (Fig. 1) [9]. When the relevant data has been keyed in, the spreadsheet will automatically compute the required information as well as plotting the graph. A JAVA applet demonstrating the actual output on the screen of the oscilloscope has also been included (Fig. 2) [10]. In another experiment for the behaviour of a governor [11], an animated GIF file (Fig. 3) [12], has been included to demonstrate the actual running of the experiment.

The implementation of these web-based interactive manuals has been found to achieve the intended objectives of reducing the time spent on laborious computation and presentation of results and freeing the students for the task of analysing and discussing the results within the class.
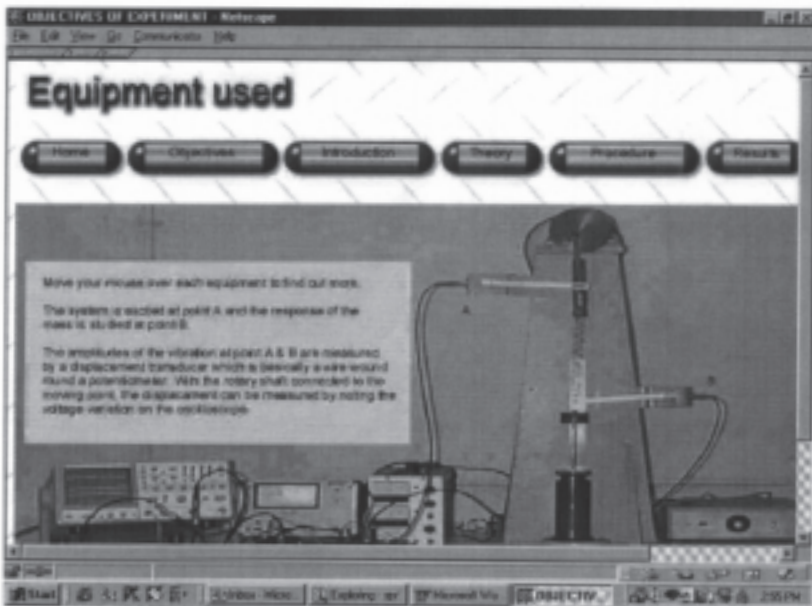

Fig. 1. Experiment demonstrating a spring-mass-damper system.

CONCLUSION

The proposed interactive laboratory manual is designed to reduce the time spent in a laboratory class for performing the laborious computation and plotting of results as well as to familiarize the students with the physical set-up before performing the actual experiment. The students can therefore spend time in the laboratory on the analysis and discussion of results with the instructors or teaching assistants. The other features include the presentation and explanation of the actual equipment and machines in the form of digital images, video clips or quick movies. The concept has been implemented for typical laboratory-based courses in engineering mechanics.
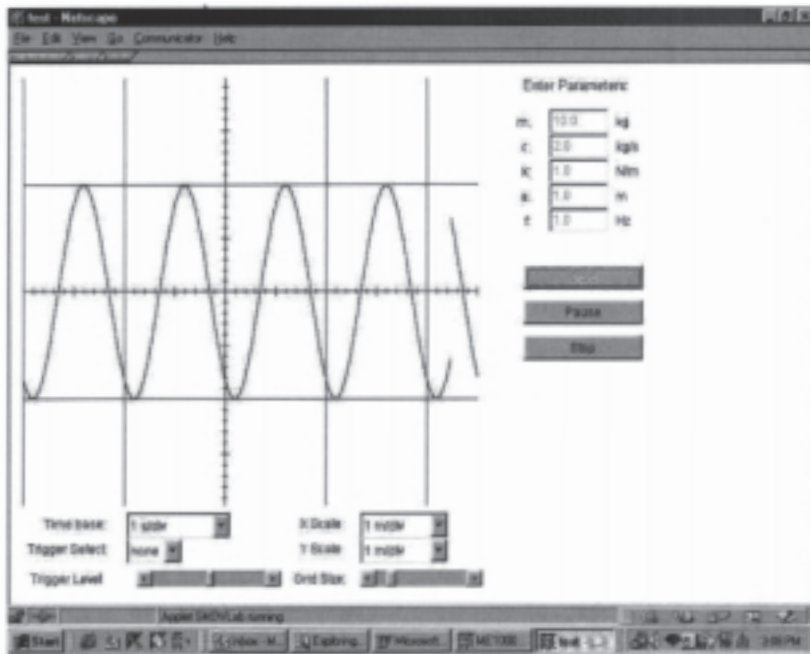
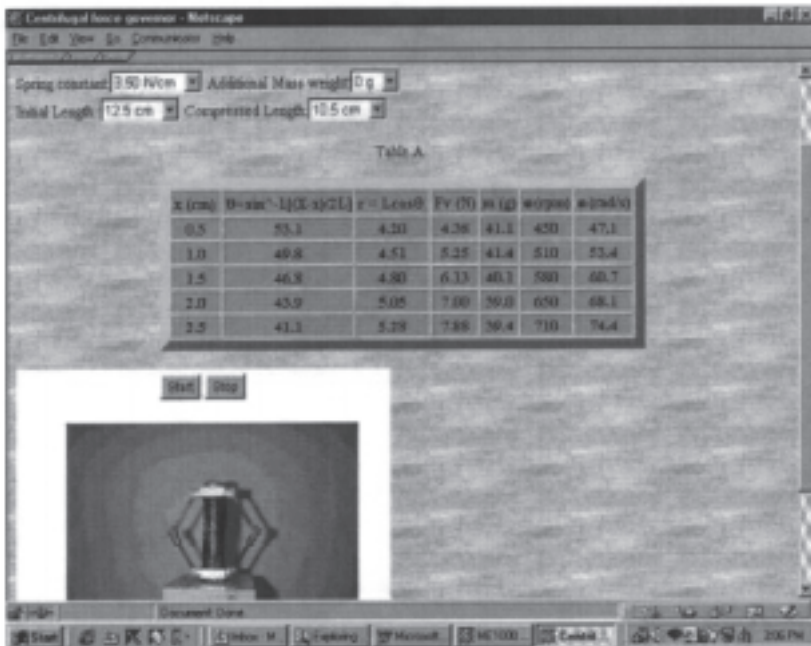Fig. 2. A virtual lab demonstrating the output on an oscilloscope.

Fig. 3. Animated GIF file demonstrating the actual motion of a governor.

It serves as a viable alternative for someone who is not yet prepared to venture into the era of virtual laboratory, and for subjects that are not amenable to being converted to virtual laboratories.

All the links in the list of references were active during the preparation of the manuscript. The author has not examined any other web sites that are either restricted or where access may be purchased.

ACKNOWLEDGEMENT

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