Economical Integration of Virtual Laboratories in EET Curricula

A. M. Ibrahim
DeVry Institute of Technology
Toronto, Ontario, Canada

Abstract

Virtual Laboratories provide interactive environment for creating and conducting simulated experiments. Integrating virtual labs into an EET curriculum has the potential of enhancing classroom delivery by establishing a timely connection between theory and practice. Virtual labs can also help institutions to cope with budget constraints without sacrificing quality. Nevertheless, developing such labs requires not only specialized expertise, but also initial and maintenance capitals, situations that can hinder their use. The objective of this work is to provide a solution by showing, through examples, the possibility of integrating virtual laboratories available for free on the Web into the EET curriculum. The examples provided cover topics typical to courses such as Mathematics, Physics, Electronic Devices and Circuits, Digital Signal Processing, and Control Systems. The objective of the labs include design, analysis and illustration of concepts. Such an approach leads to achieving the educational objectives at a reduced cost with a minimum investment of time on the part of instructors. Although the concept is illustrated using a specific curriculum as an example, it can be implemented in other ET disciplines.

I. Introduction

The use of the Internet for classroom and distance education has received increasing attention over the past few years [1,2]. Of particular interest for engineering and technology education is the use of the Internet for the delivery of virtual laboratories [3-9]. Virtual laboratories have numerous merits that they share with classical laboratories and can achieve similar objectives, such as establishing links between theory and practice and helping students visualize concepts, but at a reduced cost. The objective here is to suggest that the cost of integrating virtual laboratories can be further reduced by using the global nature of the Internet; not using it only to deliver material to one's own students. Educators who choose to use them can do so economically, i.e. with no added infrastructure or extra funding.

Numerous educators from various institutions around the world have invested time in developing virtual laboratories that are freely accessible through the Web. Many students and even instructors are discouraged from making use of such resources because of the scattered nature of resources available through the Internet. The following sections illustrate the availability of freely accessible virtual laboratories that address almost all aspects of a typical curriculum in the Electronics Engineering Technology (EET) from introductory to advanced levels. The selection of these virtual laboratories is based on their relevance, reliability, ease of access, being free, and no registration required, in addition to their accessibility by any browser. For example, the virtual labs presented by the Illinois Institute of Technology [10] were not included because they are accessible by Internet Explorer and not by Netscape. Although the emphasis here is on the EET curriculum, the idea can be extended to other Engineering Technology disciplines.

II. Virtual laboratories selected

The following is a set of virtual laboratories that are available on the Web and can be accessed freely. They are provided by well-established institutions and they are free from commercial advertisements. They incorporate introductory, intermediate, and advanced levels. Topics covered include Mathematics and Physics visualization and experimentation. In addition, they cover analysis and design related to Electrical and Electronic Circuits, Signal Processing, Control Systems, and Communication Systems. The Web address and a short review of each laboratory is provided.

Color Coded Resistance Calculator

This is an interactive applet written by Jarid B. Lukin, Electrical Engineering Department, University of Pennsylvania[11]. The user selects the colors of the resistor strips and the tolerance band; a resistor that fits the description appears along with the value of its resistance and tolerance.

Solid State Materials

This is the Web site of Educational Java applet Service (JAS)[12]. It provides, free of charge, a collection of educational applets in the area of solid state devices and materials. The applets were developed by Prof. C. R. Wie of SUNY-Buffalo with a grant from NSF. The topics include crystal structure of GaAs and Si, energy bands, Fermi level, pn junction diode, bipolar transistor, device fabrication, MOSFET devices, JFET, analog and digital circuits, and more. The site also provides links to other similar sites.

Semiconductor Physics

This site gives a set of Java applets written by Winston K. Chan, Department of Electrical & Computer Engineering, University of Iowa[13]. The set includes applets to show relations between electrons and holes, calculate Fermi level, calculate heterojunction band diagram and several other semiconductor related topics. The source code of the applets is made available.

Crystal Structures

This site is provided by the Department of Electrical & Computer Engineering, Portland State University[14]. The applets illustrate the tetrahedron and diamond crystal structures, bipolar transistor processing and masking sequences.

CMOS Technology

This is a bilingual (English/German) site that has several applets provided by Uni Hamburg, FB Informatik, AB Tech[15]. The topics include CMOS technology demonstration, simulation of simple von-Neuman computer, K-map, and several other EE related applets.

Spreading Resistance Analysis

This site from Solecon Laboratories, Inc. provides a Silicon resistivity and carrier concentration calculator[16].

Virtual Engineering Laboratories

The site provides virtual laboratories for beginning science and engineering students; they include experiments related to logic circuits, diffusion processes, robotic arm control, and several other topics. The site is maintained by Johns Hopkins University[17].

Signal Processing

This is a site provided by the Department of Electrical & Computer Engineering, University of Dayton[18]. The applets provided include: Fourier series, adaptive filtering, bandwidth demonstration, FIR design example, poles and zeros, AM demonstration, and FM demonstration.

Signals and Noise Applets

This site provides ten applets that relate to random signals and noise properties and characterization. They are maintained by G. Tong Zhou, School of Electrical and Computer Engineering, Georgia Tech[19].

Electronics and Communication Engineering

This site is provided by A. Townsend to help students understand some of the principles of Microwave and Radar Engineering at the Higher National Diploma (Australia) level[20]. The applets categories include Microwaves: waveguides, standing waves, and path calculation;

Radar: the ballistic radar equation, the pulse repetition frequency, Doppler radar, and blind speed; Cellular: fundamentals, and interference calculations; Satellite: orbits, and TVRO G/T calculations; Vector mathematics.

Virtual Control Engineering Lab

This site provides an integration of plugins and Java applets which uses the computational engine of MATLAB/SIMULINK to do simulation of control engineering experiments[21].

MATLAB Experiments

This site offers numerous file libraries for MATLAB that include 3D tools, anti-alias, GUI tools, stereo experiment, and much more[22].

PID Controller Tuning

This is a collection of seventeen applets written by Jukka Lieslehto, Automation Department, Tampere University of Technology, Finland[23]. The applets illustrate various aspects and methods of PID controller tuning.

Digital Signal Processing

This is a powerful applet written by Andrei P. Akimov, Russian Academy of Sciences, Geophysical Survey Central Experimental-Methodical Expedition[24]. The applet performs and illustrates various operations of interest in DSP such as integration of a signal, convolution of two signals, multiplication of a signal by various window functions, generation of various signal functions, performing FFT, and more. The package is available for down loading in zip format.

CMSA Digital Filter Design

This site from Westminster Department of Electronic Systems provides a digital filter design tool[25]. The sampling frequency is fixed at 2o kHz, the input specifications include filter type, cut-off frequency, and four choices of the algorithm to be used.

Interactive Digital Filter Design

This site is for the design of IIR and FIR filters with more input specifications than the one given above[26].

Simulation and Debugging of DSPs and Microcontrollers

This is a site provided by the Department of Electrical Engineering and Computer Engineering of the University of Texas at Austin[27]. The site has TMS320c30 DSP and MC68HC11 microcontroller simulators for use.

Neural Networks

This is a comprehensive bilingual (English/Japanese) site that offers a large number (over one hundred) of applets pertaining to neural networks and artificial life[28]. The categories of the topics include: competitive learning, backpropagation learning, neural nets for constraint satisfaction and optimization, artificial life, and other related topics. It is maintained by Akio Utsugi, Human
Informatics Department, National Institute of Bioscience and Human Technology, Japan.

The Virtual Physics Laboratory

This site is maintained by the Department of Physics and Astronomy of the Northwestern University[29]. It provides applets on topics such as Waves: sound waves, types of waves, and superposition; Optics: diffraction, Snell's law, and lenses; Mechanics: Kepler's laws;
Atomic Physics: the Bohr atom.

Vibrations and Waves

Dan Russell of Kettering University provides animation for visualization of concepts related to vibration and waves: sound, light, and matter waves[30].

Basic Physics

This site provides a large number of links (about 150) arranged alphabetically. They cover topics starting with "Acoustics" and ending with "Young's double slit interference". The site is maintained by the Information Center for Physics Research (ICPR), Korea[31].

Thermodynamic Equilibrium Virtual Laboratory

This site from the University of Oregon has seven virtual experiments that relate to thermodynamics[32].

Statics and Dynamics

This is a set of about twenty applets developed by investigators at Virginia Tech with a grant from the National Science Foundation. The topics include Fluid Dynamics, Statics, and Dynamics[33].

Math-On-Web

This site leads to a set of mathematical tools developed by Sheela Belur. These tools include curve fitting and integration by Simpson's rule[34].

The Integrator

This site is provided by Wolfram Research, Inc[35]. It enables the user to do symbolic integration and provides guidance on how to enter the mathematical functions to be integrated.

The Calculus Toolkit

The site offers several tools to perform specialized calculations that relate to algebra, graphing, application of derivatives and integrals[36].

Virtual Laboratory in Probability and Statistics

This is a collection of virtual laboratories authored by Kyle Siegrist of the University of Alabama in Huntsville[37]. Topics include: special models, basic probability, and basic statistics.

Mathematics and Statistics

This is a site provided by the Department of Mathematics, California State University, San Bernardino[38]. The site provides links to other sites that provide applets on topics such as statistics, famous curves, geometry, cross product, and more.

Java Plotter

This site provides a number of applets such as Ptplot for functions plotting, and PtFilter which is an interactive filter design tool in addition to some other Java resources[39]. The site is provided by the Ptolemy group, University of California, Berkeley.

III. Concluding remarks

Virtual laboratories can supplement and enhance classroom laboratories and lectures. Developing such laboratories can be expensive and time consuming; global cooperation through the Web can ease these difficulties. Currently, excellent virtual laboratories are available through the Web at no cost or obligations, but their educational potential is not fully used globally because the Web looks like a huge disorganized library; useful material is there but accessing it can be frustrating and time consuming [11]. The work presented here would make some of the excellent and freely available Web virtual laboratories more accessible for teaching and learning Electronics. It is important, however, to keep in mind that virtual laboratories do not achieve all the objectives of laboratory exercises mentioned earlier and have to be used wisely. It is also important to keep in mind that virtual laboratories should not replace physical laboratories altogether. More over, if not used with proper care, they can lead to loss of creativity, imagination, interpersonal skills, problem solving skills, and discipline among students. Like everything related to current computer technology, the URLs mentioned here and even the technology used to implement the sites may have a relatively short "shelf life". Nevertheless, this should not deter educators from making use of them now, and then adapting as change occurs.

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AHMAD IBRAHIM

Ahmad M. Ibrahim received the Ph. D. degree from McMaster University in Hamilton, Ontario, Canada. He is a senior member of the Institute of Electrical and Electronics Engineers (IEEE), a member of the Association of Professional Engineers of Ontario (APEO), the Materials Research Society (MRS), the American Society for Engineering Education (ASEE), and the International Banknote Society (IBS). He has lectured widely in the area of Electronics on three continents for a diverse population of students and presented seminars and workshops for practicing engineers. He has a wide range of research and tutorial publications in the areas of Electronics and Engineering & Technology education. He authored a book on Fuzzy Electronics published by Prentice Hall. At present, he is a professor at DeVry Institute of Technology, Toronto, Ontario, Canada.