Curriculum Evolution: Integration of Web based Resources,

Tutorial Software, and Commercial Design Tools

WOOD, Sally L.[1] & DANIELSON, Ronald L.[2]

[1] Department of Electrical Engineering, Santa Clara University
Santa Clara, California, 95053, swood@scu.edu

[2] Department of Computer Engineering, Santa Clara University
Santa Clara, California, 95053, rdanielson@scu.edu

Abstract: *Engineering education has always evolved in tandem with the development of new tools and new strategies for design and test. The intertwined cycles of engineering innovation and scientific discovery rely both on improvements in instrumentation and techniques for scientific observation and also on structured methods for converting scientific advances into readily used design methodology. Over the past 20 years the almost incredibly rapid growth in high performance computational capability, high resolution graphic displays, and network connections at increasingly more reasonable cost might appear to have revolutionary implications for society in general and education in particular. However, the consideration of previous technologically revolutionary periods provides interesting perspective. The challenge for engineering education is to use these new resources efficiently to improve the effectiveness of education, rather than simply adding them on to an already crowded curriculum or displacing important components of the traditional curriculum. Meeting this challenge will require cooperative interaction among academics in sharing resources and experience. In the same way that a system designer in industry will make economic use of intellectual property developed elsewhere rather than reinventing it, the engineering educator of the future, for the same reasons, will almost certainly make more use of interactive curricular materials and content created at other institutions. This paper will describe our experiments with and use of web based resources, custom tutorial software, and commercial design tools in undergraduate engineering courses, with emphasis on perceived impact and the differences between expectations and actual experiences.*

Keywords: *JAVA, visualization, courseware, freshman, design*

1. Introduction

The traditional lecture presentation of engineering topics supported by laboratory experience and comprehensive problem sets has been increasingly challenged over the past decade by the exponential improvement in performance of computation, graphic displays, and network connections available at a cost appropriate for everyday use by students and engineers. This trend, which has been made possible by advances in integrated circuit design and fabrication, is predicted to continue. Its impact on engineering education is due both to the increased resources available for instruction and also, more fundamentally, to the changes it has brought in the way that engineering as a profession is practiced.

One factor that has remained constant throughout this rapid change of technology is that the day is still only twenty-four hours long for the students as well as the faculty who are restructuring and delivering the curriculum. Questions about the most strategic or efficient use of that time for engineering education and the roles of instructors and institutions are currently a subject of great debate [see e.g. 3, 16]. Making decisions about how the hours will be used accentuates the tension between teaching fundamental concepts that will be the basis for future professional growth and teaching current specific technology for which a student might find immediate professional use. Communication and cooperative sharing of experience among educators and industry can facilitate a more rapid development of perspective on these issues.

Efforts to improve the effectiveness and relevance of engineering education through the use of modern technology have followed multiple strategies at many institutions. Adaptation of commercial design packages can provide students with important perspectives on how engineering is actually practiced, but these tools were not designed to teach basic concepts and are often cumbersome when used for that purpose. The evolution of software tools for from standardized windowing systems to platform independent browsers using HTML and JAVA applets has inspired some faculty to create their own web resources specifically to assist student learning in their own classes. These products can be very effective, but creating them is a labor intensive activity. In addition, "portability" to other institutions and other departments requires more than platform independence.

The technology exists to address both of these issues. Large system design methods [6, 10] use already existing "intellectual property cores" as important components of custom systems rather than reinventing all components. Each designer's time is used more efficiently, and the resulting system has more capability when using this approach, which is also characteristic of a maturing engineering discipline [7]. Education at each institution can be viewed as analogous to a complex system. Each program has specific missions, a specific context, and constraints. Similarly, instructors and curriculum developers are analogous to the IC designers, and they can consider incorporating modules developed elsewhere to improve their own courses rather then either adopting a complete curriculum from another institution or recreating all materials that will be used. Flexible tutorial modules and Web based resources can be integrated effectively into a wide variety of programs which share related objectives.

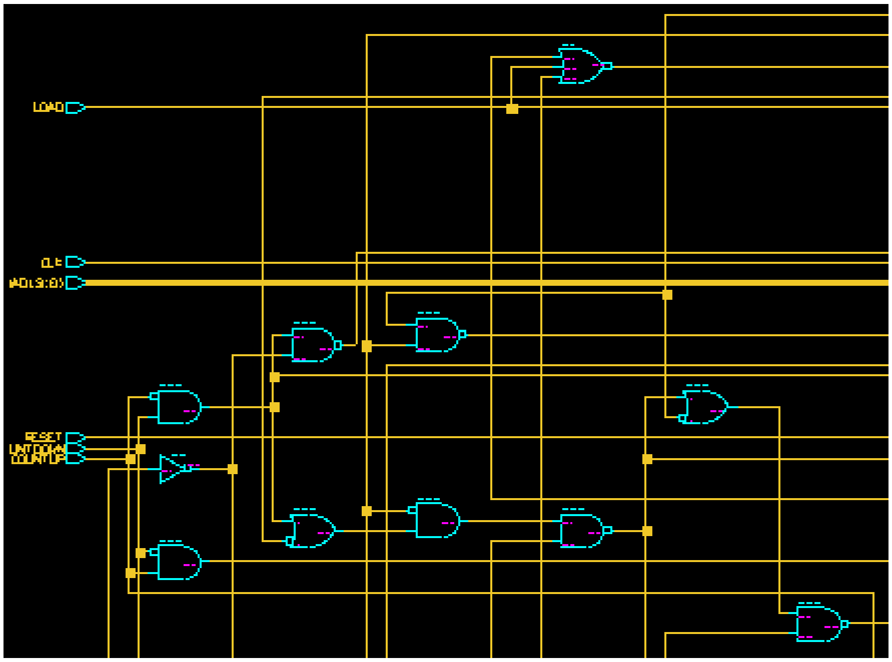


Figure 1: Part of a logic circuit designed and simulated with commercial design capture software from Mentor Graphics

2. Integration of Commercial Design Tools

Effective use of design tools is essential for the productive professional engineer. These tools allow the design of more complex systems, allow more checking and verification in the design stage, greatly reduce the repetitive components of the design process, and facilitate interaction between design team members. In a world of such sophisticated design tools, at what level should education begin and what should students know when they graduate? It could be argued that there is no reason to learn the basic things that the tools do automatically for the designer, but understanding fundamentals is also necessary for future advances. Knowing how to use a specific design tool may make an engineering graduate more attractive to a company using the same tools, but the value of that specific knowledge will rapidly become obsolete.

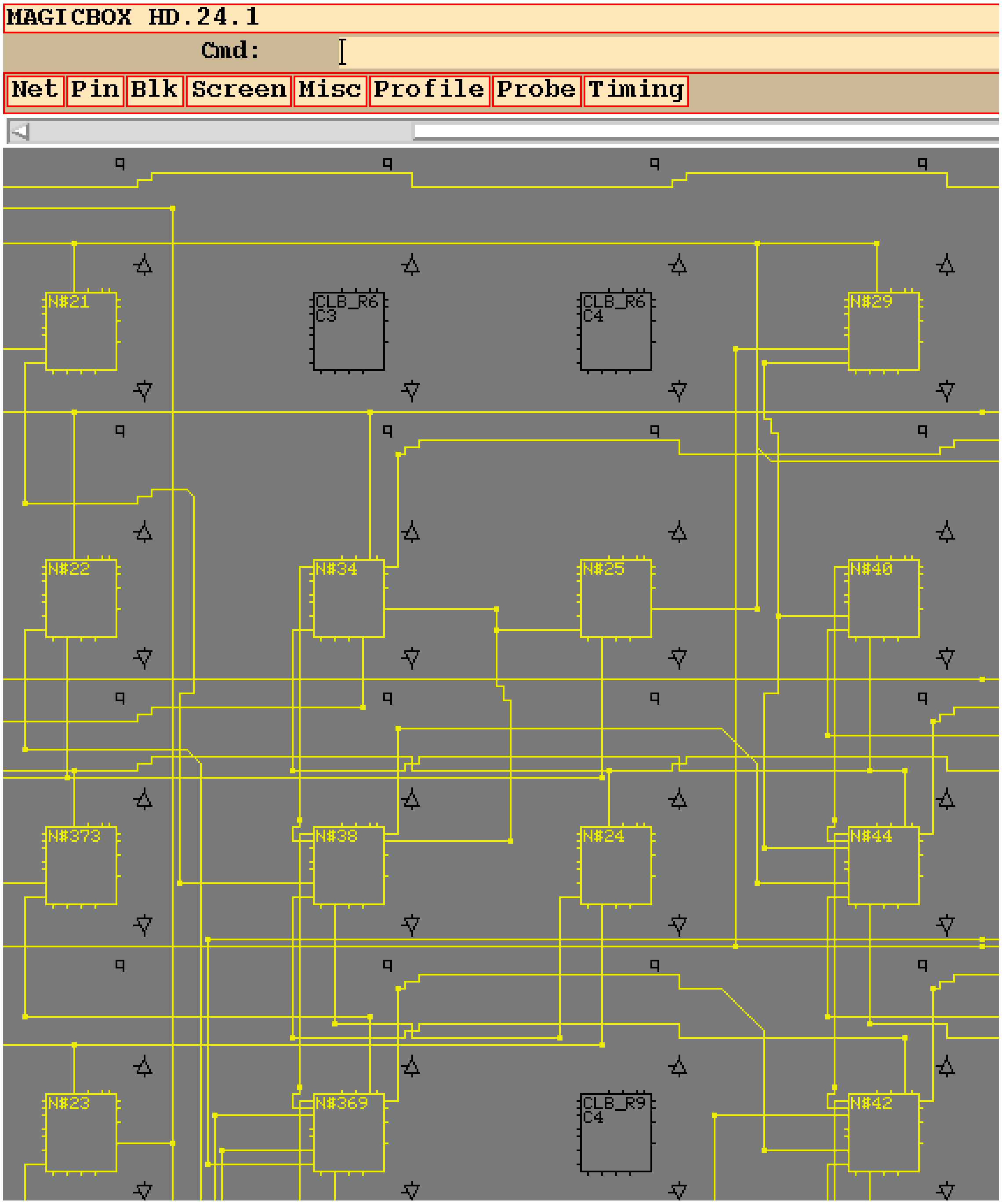
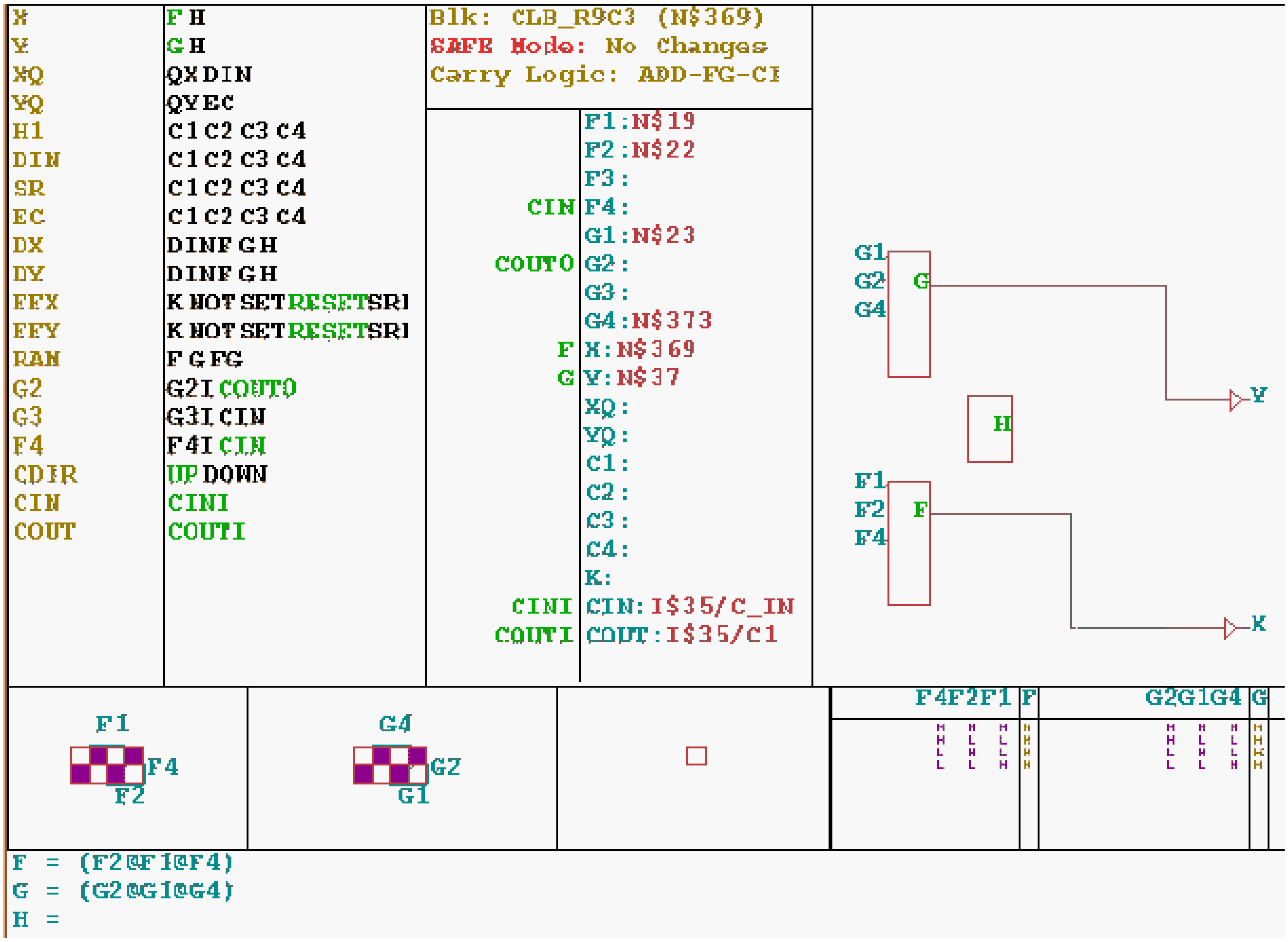


Figure 2: Routing of part of an implementation of a logic design in configurable logic blocks of a Xilinx FPGA

We have used commercial design packages for our logic design courses for ten years. The tools are currently used with Xilinx FPGAs so that the students can reasonably design and test more comprehensive circuits. This has been motivated partly by a desire to have the resources of the design tools for laboratory use. In addition, the students also need to be familiar with the types of tools used by engineers because the tools available to an engineer determine to some extent the scale and type of problems that can reasonably be attempted. However, the design tools are optimized for productivity, not for teaching fundamental concepts. The tools are also optimized for the frequent user, and often the steep learning curves discourages classroom use of a commercial package for a one term course. Effective classroom use requires integrating the tools rather than just adding them onto an existing course syllabus.



Blk: CLB_R9C3 (N$369)
SAFE Mode: No Changes
Carry Logic: ADD-FG-CI

F1:N$19
F2:N$22
F3:
F4:
G1:N$23
G2:
G3:
G4:N$373
X:N$369
Y:N$37
XQ:
YQ:
C1:
C2:
C3:
C4:
K:
CIN:I$35/C_IN
COUT:I$35/C1

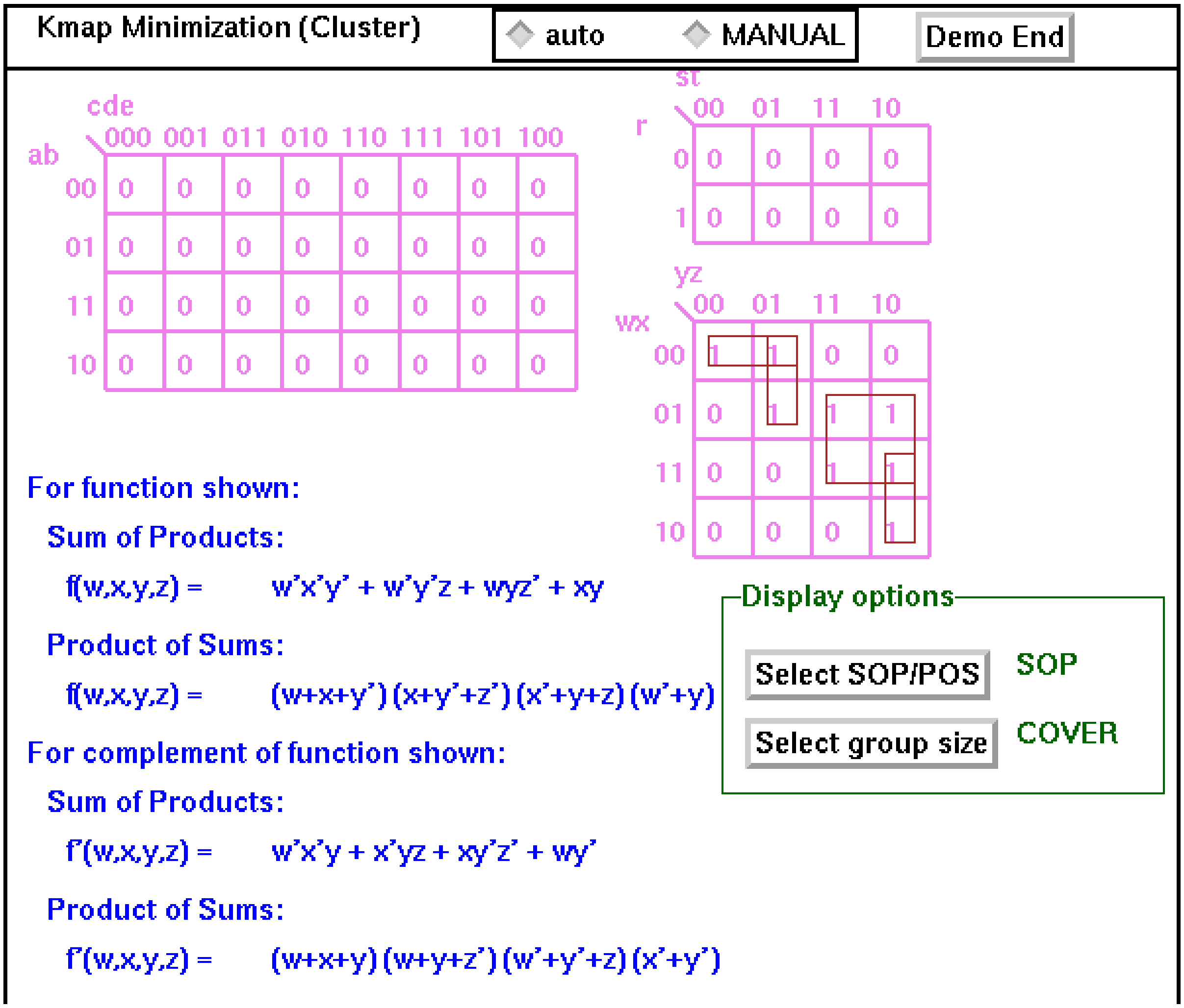
F = (F2@F1@F4)
G = (G2@G1@G4)
H =

Figure 3: Detail of one particular logic block from Figure 2.

When we first introduced design capture software and field programmable gate arrays (FPGA), the design tools and associated hardware were at a much earlier stage of development The requirement for students to learn very idiosyncratic methods and explicitly do their own placement and routing made this inappropriate for lower division introductory courses, but useful for full year senior design projects. More recently the tools have evolved and the hardware density has increased so that lower division classes can use FPGAs [20]. Students can design with gates as shown in Figure 1, and then, using standard tools, automatically implement the design in an FPGA as shown in Figures 2 and 3.

If the software tools were not available to do the detailed target mapping shown in Figures 2 and 3 from a schematic such as the one shown in Figure 1, it would not be reasonable to use as FPGA in an introductory class. The students do not become "expert users" with ready knowledge of intricate operational details of the design tools, because that is not the primary focus of the course. They do learn very basic operation and they can appreciate what the design tool can do for them as well as the benefits of modular design, systematic testing, and the concept of components. When they encounter a similar design package after graduation, they will know how to begin to learn it.

The sophomore class that currently uses the Mentor Graphics design capture and simulation tools stresses the fundamental concepts of logic design. The commercial tools are supplemented by JAVA applets [2] and interactive tutorials [19,21,22] which present the basic concepts in a dynamic visual manner to complement lectures and text book presentations. Figure 4 shows an example of an interactive tutorial developed for entry level classes in logic design. It allows students to specify 3, 4, or 5 variable functions and then observe the logically adjacent groupings and the minimum cover. Simultaneously presenting the function and it complement in both sum of products (SOP) and product of sums (POS) form emphasizes the fundamental general relationship between the representations. If only one of those four forms were displayed, the emphasis would shift to the solution of the specific problem. A related part of the tutorial asks the student to identify the groupings for the minimum cover.



ab \ cde	000	001	011	010	110	111	101	100
00	0	0	0	0	0	0	0	0
01	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0

r \ st	00	01	11	10
0	0	0	0	0
1	0	0	0	0

wx \ yz	00	01	11	10
00	1	1	0	0
01	0	1	1	1
11	0	0	1	1
10	0	0	0	1

For function shown:

Sum of Products:

$f(w,x,y,z) = w'x'y' + w'y'z + wyz' + xy$

Product of Sums:

$f(w,x,y,z) = (w+x+y')(x+y'+z')(x'+y+z)(w'+y)$

For complement of function shown:

Sum of Products:

$f'(w,x,y,z) = w'x'y + x'yz + xy'z' + wy'$

Product of Sums:

$f'(w,x,y,z) = (w+x+y)(w+y+z')(w'+y'+z)(x'+y')$

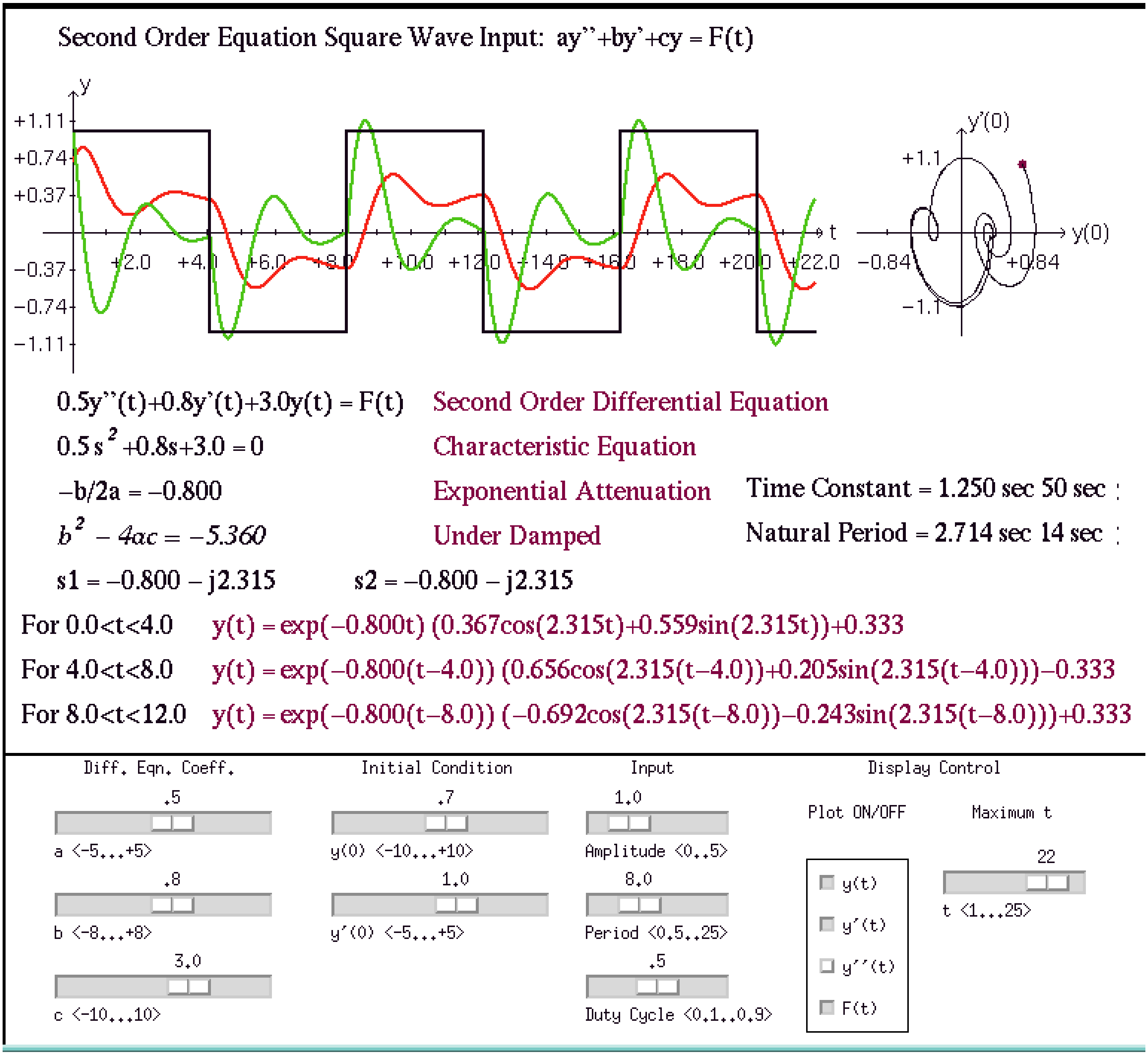
Select SOP/POS: SOP

Select group size: COVER

Figure 4: Interactive tutorial demonstrating two level circuit minimization principles developed by S. Wood at Santa Clara University

3. Visualization and Audio

Dynamic visualization using high performance computing and high resolution color displays can provide reinforcement for basic concepts, especially for multidimensional or time varying interactions. Many institutions have developed their own custom tutorials, and as more actual and de facto standards arise for hardware and software, many are adopting and/or improving tutorials generated elsewhere. We have developed tutorials for digital systems, digital signal processing, engineering mathematics, and basic concepts of computer engineering [2,19]. Over ten years these tutorials have migrated from the platform specific, network incapable Sun-View graphical user interface to JAVA applets, which have the potential for use over the network with complete platform independence.



Second Order Equation Square Wave Input: $ay''+by'+cy = F(t)$

$0.5y''(t)+0.8y'(t)+3.0y(t) = F(t)$ Second Order Differential Equation

$0.5s^2+0.8s+3.0 = 0$ Characteristic Equation

$-b/2a = -0.800$ Exponential Attenuation Time Constant = 1.250 sec 50 sec :

$b^2 - 4ac = -5.360$ Under Damped Natural Period = 2.714 sec 14 sec :

$s1 = -0.800 - j2.315$ $s2 = -0.800 - j2.315$

For $0.0<t<4.0$ $y(t) = \exp(-0.800t)\,(0.367\cos(2.315t)+0.559\sin(2.315t))+0.333$

For $4.0<t<8.0$ $y(t) = \exp(-0.800(t-4.0))\,(0.656\cos(2.315(t-4.0))+0.205\sin(2.315(t-4.0)))-0.333$

For $8.0<t<12.0$ $y(t) = \exp(-0.800(t-8.0))\,(-0.692\cos(2.315(t-8.0))-0.243\sin(2.315(t-8.0)))+0.333$

Diff. Eqn. Coeff.

.5
a <-5...+5>

.8
b <-8...+8>

3.0
c <-10...10>

Initial Condition

.7
y(0) <-10...+10>

1.0
y'(0) <-5...+5>

Input

1.0
Amplitude <0..5>

8.0
Period <0.5..25>

.5
Duty Cycle <0.1..0.9>

Display Control

Plot ON/OFF

☐ y(t)
☐ y'(t)
☐ y''(t)
☐ F(t)

Maximum t

22
t <1...25>

Figure 5: Interactive tutorial for differential equations developed by S. Wood at Santa Clara University

One significant advantage of high resolution color displays is that concepts can be visually presented in context, and new ideas can be more easily understood when the student is reminded of the framework already developed. The example of the second order differential equation in Figure 5 integrates the solution method for constant coefficient linear differential equations and the use of initial conditions. The visual presentation reinforces the concepts of transient and steady state response and phase diagrams. This type of tutorial is useful for all engineering students who must understand dynamic systems.

Our experience with tutorials such as the one shown in Figure 5 is that it provides an increased level of understanding for all students. Initially it was assumed that the average students who did not spontaneously visualize concepts would gain the most from these interactive visual presentations, but the excellent students also gained insights from their interactive experience. However, simple access to the tutorial is not sufficient. Guidance from the instructor greatly increases the students' initial ability to interpret the meaning of the responses to their inputs. The correct interpretation of an abstract visual display will depend on previous experience [4], and the strategic selection of initial parameter sets to direct the students to observe is best determined from the instructor's intuition and objectives. After following guided examples related to the course syllabus, student intuition grows and the students are more able and more likely to continue independent investigations.

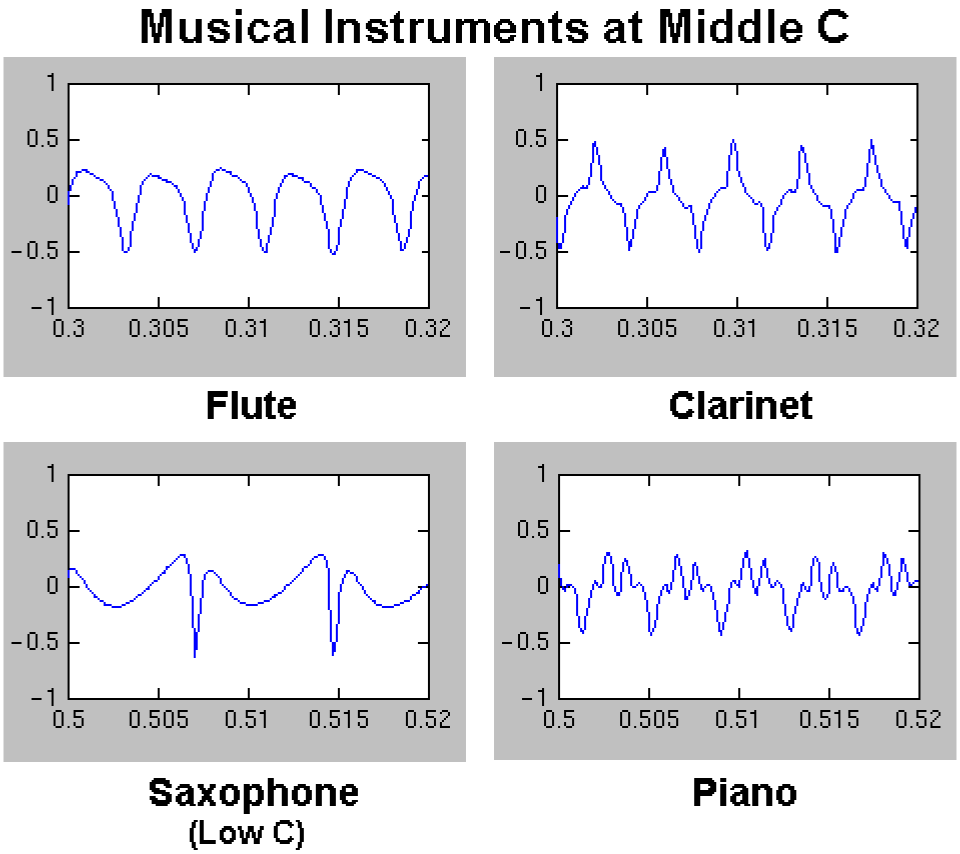


Figure 6: Periodic audio signals from a music keyboard

Audio output can be used to reinforce concepts such as periodic waveforms, harmonic content, frequency response, data rates, and modulation [21]. In addition, it can be used simply to add emphasis or to provide examples of signals that will have intuitive meaning. The signals shown in Figure 6 were created by a keyboard which simulates the sounds of a variety of instruments. The effect of the harmonic structure on the sound of waveforms with the same period is easily observed even by students with no musical training. Speech, as shown in Figure 7, is also largely composed of periodic waveforms with meaning determined by the changing harmonic content. When a student's own voice is corrupted with noise and filtered, the impact is of more interest than when the same processing is applied to an abstract signal definition.

5. Web Based Resources

Web based resources provide easy access to local course specific information, information from other remote sources, simulations and virtual experiences, and connection to other people. Animations and audio output can be used in a platform independent fashion. While this is of great benefit in individual courses, there is a much stronger potential benefit with respect to educational infrastructure. The communication provided by the web can facilitate interaction among faculty who are delivering engineering education so that costs of development in time and dollars can be shared over a wide support for mutual benefit. The class web page is very efficient when it is working, but the cost of development and maintenance in academic institutions is often not considered or supported. It is often implicitly assumed that web pages can be added at no cost. In contrast, for commercial operations the web resources are essential for business, and person hours and financial resources are allocated accordingly. This is an area in which collaboration among universities can be of great benefit.

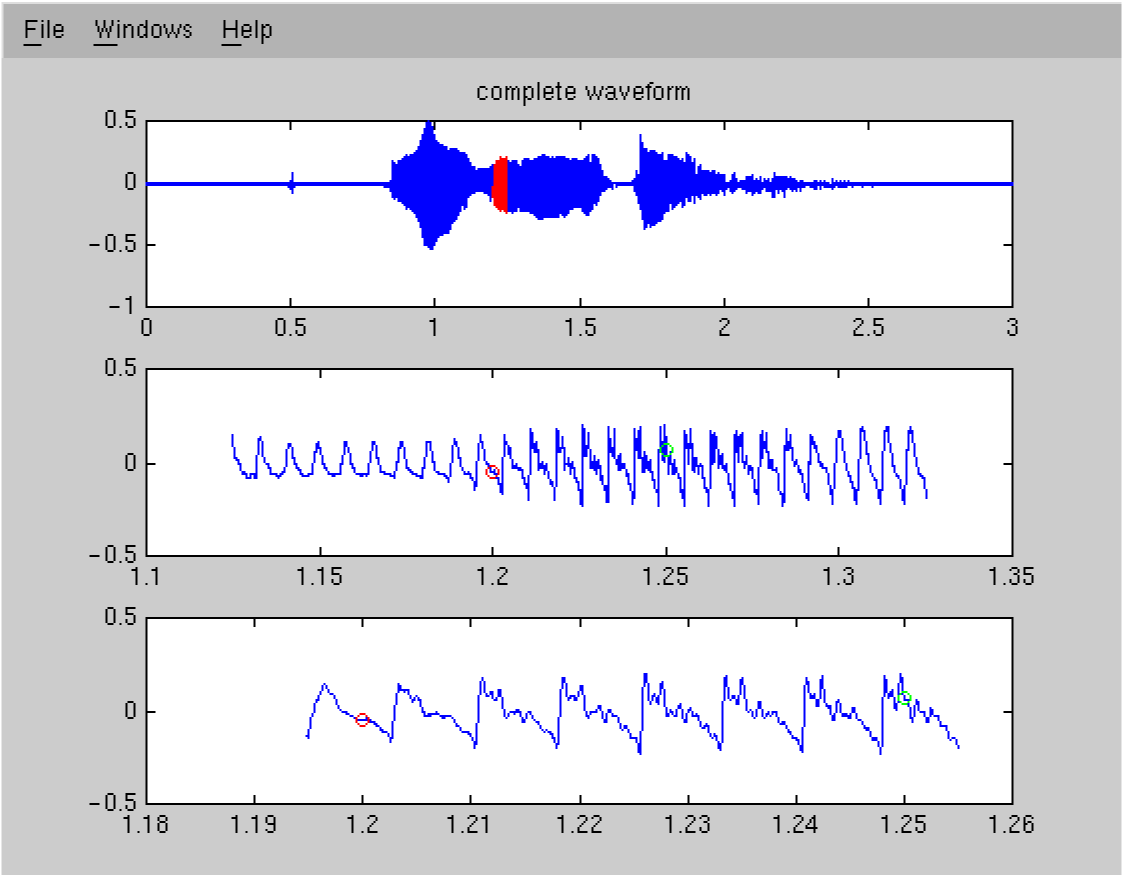
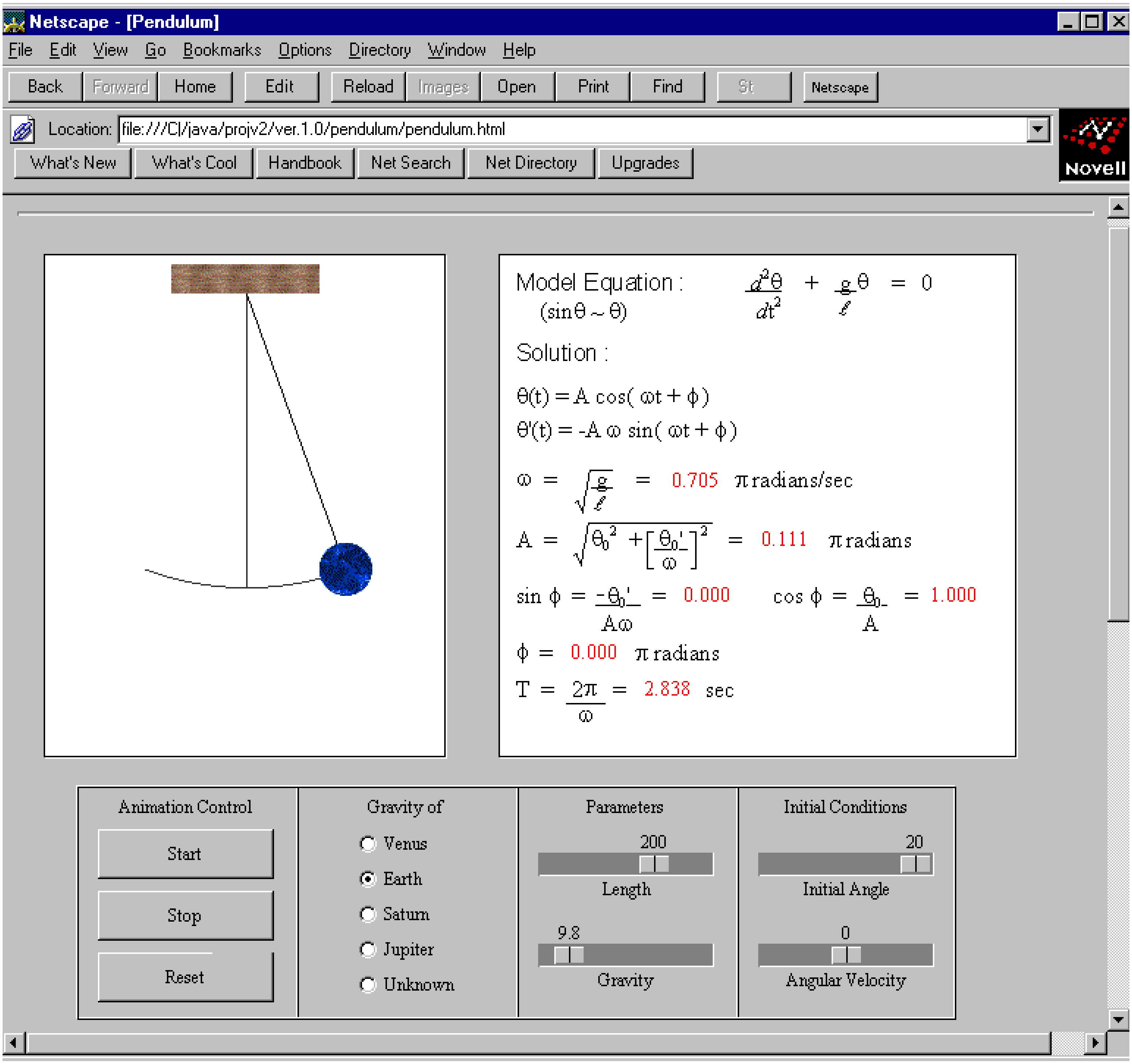


Figure 7: A recording of a student's voice introducing himself. The selected portion shows the harmonic structure of the voice waveform for the vowel "a" and the harmonic consonants "n" and "m" of "name". The highlighted portion in the complete waveform is shown in the lower plot of the figure.

6. Courses for Freshman and Nontechnical Majors

The resources developed to enhance undergraduate engineering education can also be used to support courses leading to improved technological literacy and fluency for students who are not majoring in engineering [2, 13, 14, 21, 22]. Many textbooks have been created for introductory courses in electrical engineering which cover the technical areas in a topical manner [8,12,17,18], but others which look at integrated developments and connections [1, 5, 9] may be more appropriate for both types of courses. The same interactive tutorials and Web based resources can also be used for both types [2, 21, 22].



Location: file:///C|/java/projv2/ver.1.0/pendulum/pendulum.html

Model Equation : $\frac{d^2\theta}{dt^2} + \frac{g}{\ell}\theta = 0$

$(\sin\theta \sim \theta)$

Solution :

$\theta(t) = A\cos(\omega t + \phi)$

$\theta'(t) = -A\,\omega\sin(\omega t + \phi)$

$\omega = \sqrt{\frac{g}{\ell}} = 0.705$ π radians/sec

$A = \sqrt{\theta_0^2 + \left[\frac{\theta_0'}{\omega}\right]^2} = 0.111$ π radians

$\sin\phi = \frac{-\theta_0'}{A\omega} = 0.000$ $\cos\phi = \frac{\theta_0}{A} = 1.000$

$\phi = 0.000$ π radians

$T = \frac{2\pi}{\omega} = 2.838$ sec

Gravity of

○ Venus
● Earth
○ Saturn
○ Jupiter
○ Unknown

Parameters

Length: 200

Gravity: 9.8

Initial Conditions

Initial Angle: 20

Angular Velocity: 0

igure 8: JAVA applet demonstrating periodic motion as a solution to a second order differential equation
eveloped by S. Wood at Santa Clara University

7. Assessment

Assessment of new curricular components and educational resources is essential. Rapidly developing technology simultaneously provides new resources and some disincentive to invest for fear of obsolescence. With new technology, can educational institutions accelerate the professional growth rate of students and produce students with skills that traditionally took several years of work experience to develop? Or will a new curriculum simply change the sequence of what is learned in a four year degree program and what is learned after graduation? These are open questions that universities and industry must continuously address. Although it is common to hear discussion about the declining "half life" of engineering education, most educators implicitly assume that fundamental concepts of abstraction, problem solving, mathematical and physical modeling, testing, and synthesis are necessary for effective engineering education whether the students are using slide rules and tables or Netscape.

8. Acknowledgement

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