Labview: an Interactive Teaching Tool for a Differential Equations Class

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Abstract

It is evident that computer based learning has become an essential part of education systems. It provides animation and interactive processes that are not possible with textbooks. Not only does LabVIEW have a great impact on industry, it also dramatically affects traditional academic research and teaching. A LabVIEW-based laboratory makes researchers more productive and improves the way students learn. Rather than focusing on sometimes-tedious methods of gathering data, educators and students can focus on results and concepts. In this paper, we present an Interactive Internet application of LabVIEW in computer based teaching and learning, with emphasis on the domain of differential equations applied to physical sciences. The students' experiment component is supported with both virtual and real-time remote laboratory. The discussions include the design, implementation plan, and instructional method.

Keywords: Interactive Internet based learning, Computer assisted instruction, LabVIEW, JAVA, HTML, Virtual Laboratory, Visualization, Simple Harmonic Motion, Simple Pendulum, Differential Equations.

Introduction

Along with the advancement of computers and the advent of the Internet, the field of education has taken on new dimensions. This new technology includes Internet based research and learning and serves well as complimentary tools in education. In this paper, we develop an interactive web based activity that is aimed at teaching differential equations concepts through applications in physical sciences and problem solving to college juniors and seniors. It involves the development of an interactive web-based learning environment for basic differential equations concepts. The major objectives are: students' understanding enhancement, problem-solving skills improvement, and instructional theories and methods enrichment.

Differential Equations is an area where engineering students find difficulties in understanding basic concepts, solving problems and applying them to different fields. This is due to several reasons that include the tedious nature of theory such as the use of higher order differential equations, and the analysis of systems of differential equations [5, 7]. There have been several attempts to employ available technology and World Wide Web to resolve various problems encountered by students [3, 4].

The basic design includes guide, simulation/visualization, web-interaction, and help sessions. The guide provides expert opinions to students. It guides them on topics relevant to solving the problems. The simulation and visualization sector is very important in areas such as differential equations where many tools and methods are not easy to follow and comprehend. In our teaching method, students get enough chances to solve the problems. The implementation will be achieved using HTML, graphical

programming language G (LabVIEW), and Internet Developers Toolkit for G. Some visualization simulations will use JAVA applets that are programmed to pop up in a new window. LabVIEW makes it easy to provide both virtual and remote laboratory experiments to students. Clients with passwords could access this tutoring/learning system, including the virtual and remote laboratories, via a web browser in any computer (without LabVIEW application) connected to the Internet. There are several research groups working on computer based learning systems that employ LabVIEW [3, 8, 6, 4]. This paper presents the component of the tutoring system that involves the Internet application of LabVIEW for Virtual Lab and real-time remote laboratory experiments.

Fundamental Issues

In designing the framework for an interactive computer/Internet based learning instructional systems and intelligent systems, there are fundamental issues that need to be addressed. These issues surround the communication of knowledge to the student. In designing computer assisted instruction and Internet based tutoring systems one needs to consider the domain, student, communication strategies, and the interface. The design of the path/navigation through the proposed interactive internet based computer-assisted instructional system is shown in Figure I. This is a modification of the structure presented by Shute and Psotka [9, 6].

Figure I
The design of the path/navigation through an interactive internet based computer assisted instructional system
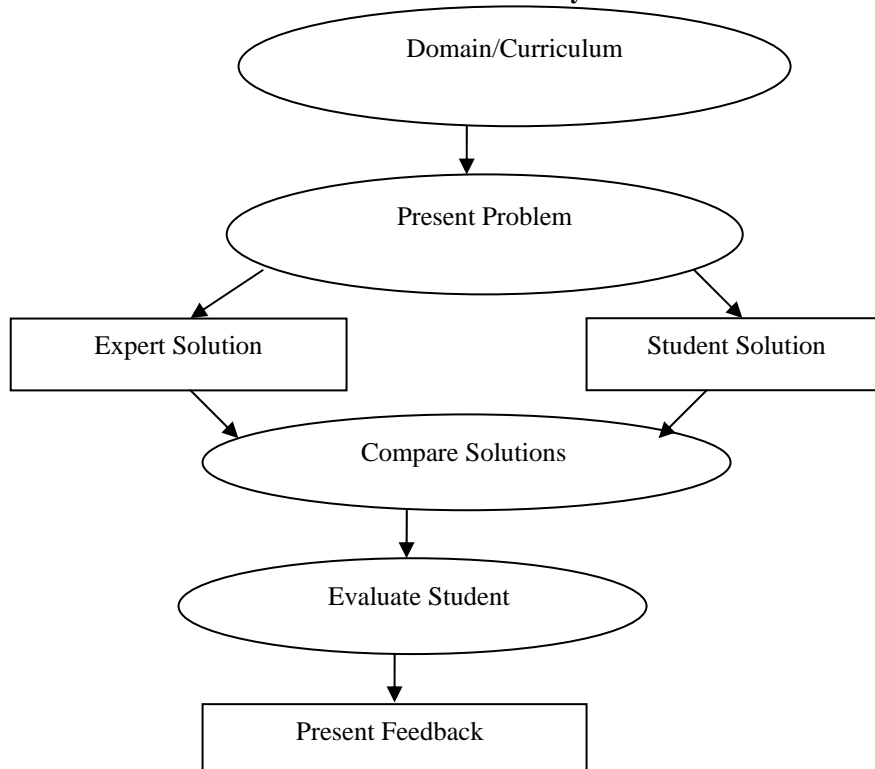
The Domain Knowledge

It is necessary to have excellent expertise in the domain of instruction in order to be a good source of the knowledge to be presented. The organization of the knowledge for easy communication to the student, and for best representation and understanding of concepts and their applications are important. In the domain of differential equations, the knowledge to be conveyed to the student must be organized to avoid misconception of abstract and invisible concepts such as resonance, steady state, damping, etc.

Knowledge of the Students

It is important to understand the behavior of the student, previous knowledge and experience of the student that might affect his/her learning characteristics, and the adaptability to the instructional system. Building knowledge about the student need appropriate diagnostic techniques. In differential equations for example, preliminary questions and problems could be used in assessing the student's previous knowledge and experience. One could identify any misconceptions by analyzing the student's response to questions and problems. This will be useful in determining the next set and level of problems, the type of visualization aids and simulation of concepts, and the method of materials presentation.

Pedagogical Knowledge

Communication strategies are important part of the set up. In differential equations, one must be sure that the way materials are presented will not lead to misconceptions. This is important in using animation for visualization purposes. One must exercise good judgment in deciding when, where, and how to present animation JAVA applets, virtual laboratory experiments, and real-time remote lab experiments. Good communication skills however need good understanding of the materials to be presented, the audience or recipient, and the available interface or means of communication.

Interfaces with the Students

The interface component also need knowledge of the above three components. For example in direction fields, the knowledge about the student will determine if graphical presentation will be adequate or there will be need for animated JAVA applet images. Some other questions may include how problems, responses and feedbacks are handled; how many interactive windows are needed; and should a pop-up new window used? These are few of the many issues that need to be addressed.

Design and Implementation

The basic design includes guide, simulation/visualization, web-interaction, and help sessions. The guide provides expert opinions to students via MOODLE interactive software using Virtual Lab and real-time remote laboratory. In LabView, we can solve ODEs using one of seven Variable Integrals (VIs) for solving first and higher order

differential equations. Most of the vibrations encountered in engineering applications can be represented by a simple harmonic motion. Many others, although of a different type, can be approximated by a simple harmonic motion, provided that their amplitude remains small. The three main applications are simple pendulum, spring mass system, and AC circuit. We demonstrate the Lab View approach using a simple pendulum, consisting of a bob of mass m attached to a cord of length l, which can oscillate in a vertical plane. At a given time t, the cord forms an angle θ with the vertical. The objective of the following exercise is to demonstrate the solution of a second-order differential equation. We show in this exercise how to incorporate the Substitute Variables VI in order to vary the model parameters. The pendulum model is given by

$$\frac{d^2\theta}{dt^2} + \frac{c}{ml}\frac{d\theta}{dt} + \frac{g}{l}\sin\theta = 0, \tag{1}$$

where m is the mass of the bob, l is the length of the rod, g is the acceleration due to gravity, and θ is the angle between the cord and a vertical line passing through the equilibrium position. The model is a homogeneous, linear, second order differential equation. LabView gives us three choices of integration VIs: ODE Cash-Karp 5th Order, ODE Euler Method, and ODE Runge-Kutta 4th Order. However, these three integration VI's are suitable for first-order systems. The first step is to convert the pendulum model to a system of two first order differential equations. Applying the substitution:

$x_1 = \theta$ and x2 = $\dot{\theta}$ to equation (1) gives the system

$$\dot{x}_1 = x_2$$
$$\dot{x}_2 = -\frac{c}{ml}x_2 - \frac{g}{l}\sin x_1. \tag{2}$$

Figure II is the front panel of the VI that simulates the motion of the simple pendulum.

Figure II
Simulating the motion of a pendulum-front panel
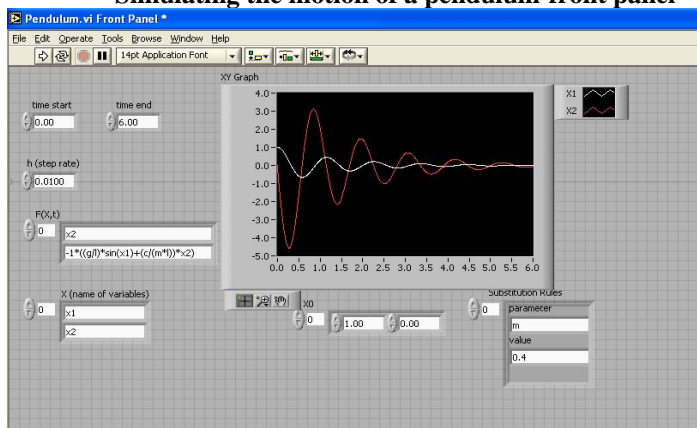
Furthermore, a block diagram that can be used as a guide in the VI development is shown in Figure III. To begin the development, we use the ODE Euler Method VI. The inputs that will be needed are X (an array of strings listing the dependent variables x_1 and x_2), time start (the point in time at which we start the calculations $t_0=0$), time end (the point in time at which to end the calculations $t_f = 6$), h (the time increment at which we perform the calculations h= 0.01), and X_0 (the initial conditions $x_1(0) =1$, and $x_2(0) =0$).

The pendulum differential equations are typed in the F(x, t) control. The VI uses the Substitute Variables VI as a vehicle for varying the pendulum parameters. This allows students to enter the pendulum model on the front panel and then to substitute numerical values for *m, l, g* and *c*. Students can change these values to further investigate the effect of these parameters on the system response. In addition, students can, also, change h (step rate) from 0.01 to 0.1. The system response is no longer stable. Since nothing has changed with the physical model, so this instability must be due to the limitation of Euler integration scheme. Therefore, students will have more than one chance and tool to solve the problem at hand. These tools are either analytic or numeric.

Figure III
Simulating the motion of a pendulum –block diagram
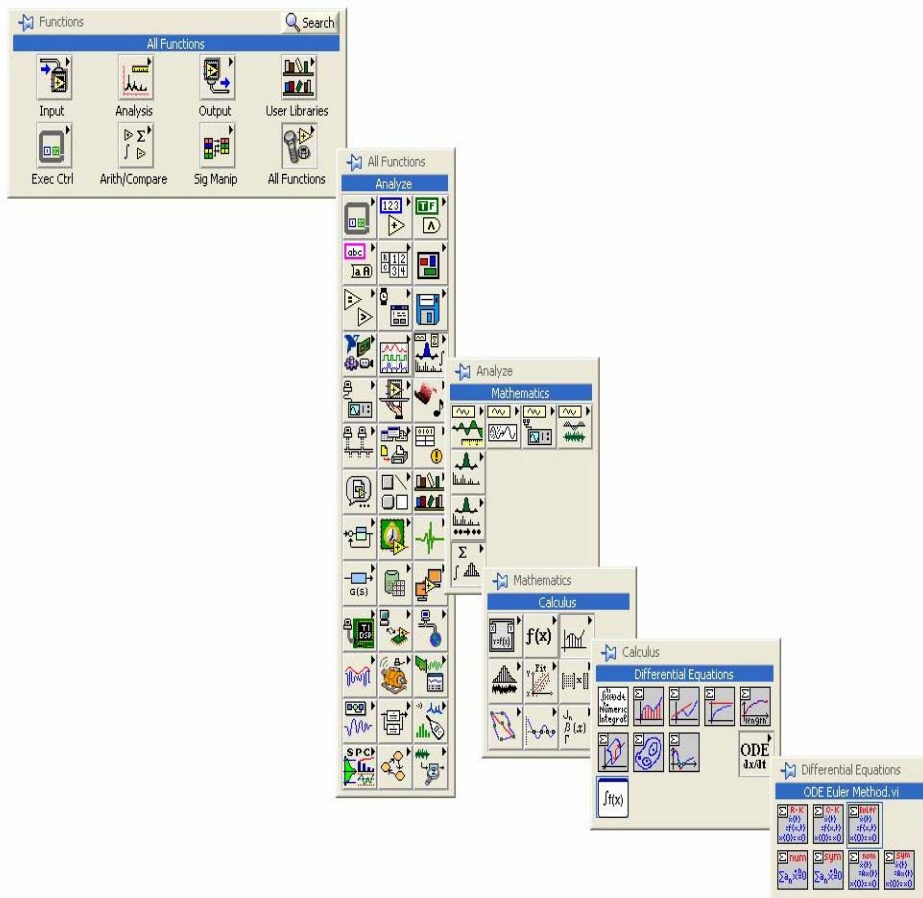
Conclusion

The framework for an Internet based tutoring/learning system that uses LabVIEW to present an experiment in the domain of differential equations have been designed .The experiment's component is a hybrid of a virtual lab and a real time remote laboratory. Authorized user from a web browser via the Internet could access both labs. The basic design of the remote lab of the motion of a simple pendulum has been presented to demonstrate how LabVIEW and its Internet Toolkit can be used to implement the virtual laboratory. Also, differential equations analysis tools are included in the virtual lab component. This tutoring system will serve as an excellent compliment to classroom teaching and learning of Differential Equations. Our ultimate goal is to design more labs in the differential equations area and to extend this idea to other mathematics courses.

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