Topic-Specific Learning Management Systems through Self-Contained Applets

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Abstract—Java applets have long been used to facilitate interactive simulation of physical phenomena and to thereby enhance the understanding of a given topic. However, the full potential of their scope and power remains to be tapped. The present work highlights, with the help of specific examples, how a Java applet may be used to play the role of a topic-specific learning management system. Such an applet would contain, all of the relevant theory, experimentation in the form of simulations, quizzes, provision for gathering feedback, posting questions and receiving answers, participating in a discussion forum, as well as linking to additional resources. The different components, stacked in neatly arranged panels within the applet, would be visible to the learner at all times. This way, the learner can correlate the role played by the different components, making learning of the given topic easier, faster and a more enjoyable experience. With the template of such an applet in place, it would be easy for individual teachers to adopt such a system to teach any topic in an on-line as well as off-line environment. Such applets may also find use in presenting the results of a research finding to an uninitiated audience, as has been explained with the help of another example.

Index Terms—E-Learning, Java applets, Topic-Specific Learning Management Systems.

I. INTRODUCTION

History has been made on 1st of April, 2010, with the coming into force of the ‘Right to Education Act’ in India. The law makes it legally enforceable for every child in India between the ages of six and fourteen to demand and receive free and compulsory education. With over two hundred million children coming under the purview of this act, its successful implementation would require the creation of a huge number of new schools and recruitment of a huge number of qualified teachers. Many more colleges would also have to be created to accommodate the increasing number of pass-outs from the schools. The costs involved would be stupendous and would surely act as impediments. This is where ‘E-Learning’ can play a very positive and helpful role. The government has already taken a few initiatives in this regard through its arm, the University Grants Commission. We teachers of science, too, can contribute in our own small ways. Let us examine how.

Virtual simulations of laboratory experiments and those helping to elucidate theoretical concepts form an integral part of ‘E-Learning’ in science and science-based subjects. Many an initiative has been taken in this regard, especially in the last few years [1,2,3,4,5]. Their impact on physics education has also been studied [6,7]. Most of these initiatives take the help of Java applets, which are small programs that are temporarily downloaded onto the user’s computer and executed. These applets, through which the simulations may be carried out, are embedded inside a parent HTML page. In some cases they may be downloaded and saved inside the local computer and executed off-line. It is important to note that most of the applets are designed more as tools to partially supplement the theoretical understanding rather than provide complete knowledge on a given topic. As a consequence, very little theory, which may only include the working formulas, is provided alongside. This little bit of theory, along with the instructions on how to use the applets, are incorporated in the HTML page housing the applets or in separate files, which may be downloaded for off-line use. Hyper-links, which enable the learner looking for more information to navigate to other websites, web-forms through which the teacher may collect feedback and queries from the students, links to discussion forums in which the student may participate to share his viewpoints on particular topics, are few of the other features that may be found inside the parent HTML page. However, with the rapid rise in both the speed of the Internet and its affordability, there is no reason why we cannot create and make use of larger sized applets, housing most, if not all of the features stated above, in neatly arranged panels within themselves.

The present work highlights, with the help of a couple of examples, how Java applets with designs as stipulated above, may be used to play the role of small, topic-specific learning management systems in imparting cost-effective on-line and off-line education to the students and learners. Such applets may not only help reach students and learners without access to proper laboratories and teachers, but may also help in making difficult topics more understandable, and learning as a whole, an enjoyable experience. The present work goes on to demonstrate, through another example, how similarly designed applets can be used to present the results of a research finding to an uninitiated audience, in an entirely novel and exciting manner.

II. OUR FIRST APPLET: EXPERIMENTING WITH A PARALLEL RESONANT CIRCUIT
The first applet that has been designed pertains to an experiment to study parallel resonance in an electric circuit. A similar applet to facilitate the study of resonance in physics had been designed quite recently [8]. The parallel resonance experiment enables one to isolate and extricate the Fourier components in a periodic non-sinusoidal signal. Students of Physics and Electronic Science perform this experiment as part of their laboratory-work in the first year of college. Prior to performing this experiment, the students are taught the theory behind Fourier series and how different periodic, yet non-sinusoidal functions can be expressed as a sum of Fourier components. They are also taught the theory behind parallel resonance in an electric circuit and how such a circuit may be employed to extricate a desired harmonic component from a periodic non-sinusoidal input by changing the frequency of the input to a suitable value such that the frequency of that harmonic component equals the resonant frequency. Teaching all these topics in the class usually consumes quite a few lecture hours. The laboratory, too, needs to be equipped with costly equipments like a function generator to generate the periodic non-sinusoidal signals and a cathode ray oscilloscope to view the output waveforms. All these constraints can be overcome through the use of the ‘Experimenting with a parallel resonant circuit’ applet, a screen-shot of which is shown in Fig. 1. As can be seen, the applet is divided into four rectangular panels. The parallel resonant circuit is shown in the top-left panel. The entire theory, including that of parallel resonance and the mathematical expressions for the Fourier series of select, periodic, non-sinusoidal waveforms, has been accommodated in the top-right panel. This panel has a vertical scrollbar for helping to navigate to any part of the theory. The bottom-left panel has text-boxes with the help of which one may fix the values of the circuit parameters, viz., the self-inductance (L) and its own resistance (r_L), the capacitance (C) and the resistance (R). The values of L, r_L and C fix the value of the resonant frequency of the parallel resonant circuit. One may also select the type of input waveform from a drop-down list. The selected waveform along with its Fourier components is displayed in the bottom-right panel. In Fig. 1, the selected waveform being the full-wave rectifier output, the same waveform along with its dc component and the even numbered harmonics are displayed in that panel. Pressing the ‘Continue’ button at the bottom of the bottom-left panel displays a horizontal slider as shown in the bottom-left panel of the applet in Fig. 2. By changing the position of the slider knob, one may vary the frequency of the input signal and observe its effect on the output waveform in the top-right panel. If the input signal contains an nth harmonic component, then selecting an input frequency equaling 1/n times the resonant frequency would result in all the other Fourier components except the nth harmonic being attenuated and dropped across R. This happens because the frequency of the nth harmonic now equals the resonant frequency. The output waveform would therefore resemble the nth harmonic. The top-right panel of the applet in Fig. 2 shows how the output waveform in black resembles the fourth harmonic in blue when the input (full wave rectifier output) frequency (3976 Hz) is close to one-fourth of the resonant frequency (15995 Hz). The waveforms pertaining to the other Fourier components are also seen to be attenuated. Using the same procedure, one may extricate all the harmonic components present in the input signal. The situation changes remarkably when the input frequency is changed slightly. As is depicted in Fig. 3, the frequency of the nth harmonic, like the frequency of all other harmonic components, no longer equals the resonant frequency. As a result, none of the harmonic components are attenuated appreciably and the output resembles no harmonic in particular. One may enlarge the voltage scale or the time scale by using the ‘Click to zoom’ buttons provided on the waveform display panels. One may also view the ‘Frequency spectrum’, a plot of the amplitudes of the different Fourier components versus the input frequency. The amplitude of the highest harmonic present is normalized to 1 and the amplitudes of other harmonics are plotted relative to it. The amplitude of the nth harmonic is plotted at a value of the input frequency equaling 1/n times the resonant frequency. To accommodate the large range of frequency values, log \(_{10}\) of the input frequency values are used in the plot.

III. OUR SECOND APPLET: EXPERIMENTING WITH THE P-N DIODE

While the previous example showed how one might use a Java applet to learn the whole of the theory and then perform a virtual simulation of the pertinent experiment, thereby helping understand the subtle features of the topic, the second example shows how, apart from the theory and experimentation, many more features can be added to a Java applet to make it possible for itself to be called a topic-specific learning management system. The ‘Experimenting with the p-n diode’ applet, a screen-shot of which is shown in Fig. 4, is housed inside a frame, which in Java parlance is called a ‘Jframe’. At its top-right corner can be seen three buttons, using which the applet can be minimized, maximized or closed. The frame may be moved around with the help of the mouse, keeping the left mouse button pressed all along. There are six equal sized panels inside the applet frame. The top-left panel contains information pertaining to the present state of the applet. The bottom-left panel contains the controls required to perform the necessary simulations. The top-middle panel contains the pertinent plots or the drawing canvases. The top-right panel contains the tabulated data corresponding to the plots or highlights the steps to be followed to calculate a relevant parameter through a simulation. The bottom-middle panel contains a dynamic picture of the experimental set-up with all the circuit-connections. It has been deliberately made to resemble the actual set-up one usually encounters in the laboratory. And finally, the bottom-right panel contains links to other relevant information and supplementary
features of the applet. Clicking on the links opens up the related feature in the same panel.

So, what are the things that we may accomplish with this applet? Using it, we may perform simulated experiments to learn how to obtain static & dynamic diode characteristics, learn how the characteristics change with temperature and also learn how to graphically obtain the static and dynamic resistances from the diode curve.

To obtain the static and dynamic characteristics, one has to first select the value of the external resistor \( R \) using a slider-control in the bottom-left panel and then select successive values of the supply-voltage \( V_S \) using the appropriate control in the same panel. The resultant values of the diode-voltage \( V_D \) and the diode-current \( I_D \) along with the corresponding values of \( V_S \) are dynamically tabulated in the top-right panel and the data-points are plotted in the top-middle panel, yielding the so-called static and dynamic diode curves. It is interesting to note that each change in the values of the parameters \( R, V_S, V_D \) and \( I_D \) is at once reflected in the virtual experimental setup housed inside the bottom-middle panel. Following the appropriate link in the bottom-right panel, one can access the numerical solution of Shockley’s equation for the diode, which has been made use of to obtain the diode-current. There is also a provision for viewing a demo of the above procedure. Fig. 4, is in fact, a screen-shot of the demo. The contents of the various panels of the applet remain the same and have already been described above.

The behavior of the diode \( I_D-V_D \) curve with change of temperature is quite intriguing. It may seem apparent from Shockley’s equation for the diode, depicted in the bottom-right panel of the applet in Fig. 4, that the diode curve would shift to the right with increase in temperature. The diode current, however, has an implicit dependence on temperature through the reverse saturation current which approximately doubles for every 10 degree rise in temperature. Consequently, the diode \( I_D-V_D \) curve shifts to the left with rise in temperature. This aspect, as can be seen in Fig. 5, is beautifully depicted through the applet. One may select the temperature from the drop-down box in the bottom-left panel and observe the change in the diode \( I_D-V_D \) curve in the top-middle panel. He may refer to the analytical expression for the temperature dependence of the reverse saturation current along with other aspects of the relevant theory in the bottom-right panel.

Finally, one may obtain the dc or static resistance \( R_D \) and the ac or dynamic resistance \( r_D \) of the diode by following the appropriate link in the bottom-left panel, drawing the diode static characteristic curve in the top-middle panel and clicking on any point on the curve. The relevant steps used to obtain \( R_D \) and \( r_D \) can be seen in the top-right panel and the relevant theory can be viewed in the bottom-right panel by following the appropriate link. Fig. 6 shows a screen-shot of the applet as it is being used to calculate the ac resistance at a particular point on the static \( I_D-V_D \) curve.

In order to have the diode applet play the role of a small learning-management-system, some innovative features like a quiz and provision for looking for more information on the topic have also been included in the applet. Moreover, a PHP form has been designed and integrated with the applet for the purpose of posting questions and receiving answers. A provision for using a discussion forum has also been made. These features can be accessed from within the applet itself by following the relevant link in the bottom-right panel. Fig. 7 is a screen-shot of the bottom-right panel containing the above-mentioned links. Fig. 8 is a screen-shot of the quiz panel. One may participate in the quiz relevant to the given topic by clicking on any one of the multiple-choice answers. A correct answer is greeted with the sound of clapping hands and an automatic increment of the score in the box below. A wrong answer fetches a sound of disappointment. A unique feature of the quiz is that one may navigate through the other panels in the applet, looking for answers in the middle of participating in the quiz itself.

IV. OUR THIRD APPLET: PRESENTING THE FINDINGS RELATED TO A RESEARCH TOPIC

In the earlier example, we saw how a topic-specific Java applet may be used as an all-encompassing learning tool. In the third and last example, we see how such an applet may be used to present the results of a research finding. For illustrative purposes, a Java applet, depicted in Fig. 9, has been designed to help present the results of a research on electron-density based dynamics of many-electron systems under intense laser fields. In an earlier work [9], the efficacy of a single generalized Schroedinger equation in obtaining the ground state energies of the full spectrum of noble gas atoms in an appropriately scaled cylindrical coordinate system was tested. In the present work [10], the same equation and the same algorithm have been used to study electron-density dependent phenomena in the atomoscent domain in a Helium atom, as also in other many-electron atoms, under a linearly polarized intense laser field in scaled cylindrical coordinates. It has been found that the electron density oscillates perfectly in phase with the electric field. The density far away from the nucleus is more affected by the field than that close to the nucleus. However, when the field returns to zero, the overall density squeezes back towards the nucleus. These subtle aspects of the research findings may be demonstrated with the help of an animation of the contour and surface plots of the electron density. The top-right panel of the applet contains such an animation with appropriate controls to start and stop the animation. One may select the many electron system to be studied as also the strength of the laser electric field with the help of the pertinent option boxes in the bottom-left panel. The
relevant theory pertaining to related topics may be accessed from within the applet by using the links in the bottom-right panel. Provision for sending and receiving feedback as also for discussing the research topic in a dedicated discussion forum has also been made. The panel borders, in this case, have been kept invisible to increase the visual appeal of the applet.

V. SUMMARY AND CONCLUSION

The present work highlights, with the help of specific illustrations, how a Java applet may be used to play the role of a topic-specific learning management system. Such an applet would contain, all of the relevant theory, experimentation in the form of simulations, quizzes, provision for gathering feedback, posting questions and receiving answers, participating in a discussion forum, as well as linking to additional resources. The benefit that would accrue from such a design is manifold. Since the applet would have a size not greater than that of the display-screen, all the main components of the applet stacked in the different panels, would be clearly visible to the learner at all times. The learner would then be able to, say, watch a simulation of an experiment in one panel and browse the related theory or equations in another panel, all at the same time, without having to scroll up and down a long HTML page or jump between HTML pages. This way, the learner can relate the experiment to the theory, better and faster. The notion of a subject-topic being segregated into a theoretical part and an experimental part would also cease to haunt the young minds. This, in turn would lead to better and more complete understanding of the subject-topic. The all-encompassing design of the applet would also help foster intuitive links between different aspects of the given topic. With the template of such an applet in place, it would be easy for individual teachers to adopt such a system to teach any topic in an on-line as well as off-line environment.

An important feature of the applets worth reiterating is that the simulations have been designed to cater to the intelligent student who can perform the experimentation with the knowledge of the theory, as also to the less intelligent one who needs a laboratory instructor to show him the way. This feature is best highlighted in our second applet. The demo feature included in the applet plays the above-mentioned role of the laboratory instructor. The intelligent student has the option of skipping this feature and start the virtual experimentation all by himself. The teacher or instructor, however, is always made accessible to all the students, irrespective of their level of intelligence, through the use of a PHP form.

Another feature of our applets, brought out best in the second example, is the use of virtual experimental apparatus closely resembling the ones actually used in the laboratory. The dynamically changing figures in the meters and power supplies give the student performing the virtual experimentation a classroom feel. Moreover, the automatic generation of data-tables and graphs makes the use of the laboratory notebooks and graph paper redundant. Also, the display of the voltage waveforms in a rectangular panel, as has been done in the first applet, mimics the voltage profiles one would observe on a cathode ray oscilloscope (CRO) screen. The zooming features of the time and voltage axes incorporated in the applet, heightens the resemblance with a CRO. All this makes one thing clear. In situations where there is no way a student can have access to a classroom laboratory, the virtual laboratories incorporated in the applets have the potential of filling the vacuum.

Finally, applets like these, may also find use in presenting the results of a research finding to an uninitiated audience, as has been shown with the help of the third applet. Results of research are often best understood in pictorial form. If the results involve dynamically changing values in three-dimension space, an animation helps us to follow the dynamics more succinctly. Add to it, interactive user controls to see how the results change for different systems and parameters, a complete theoretical explanation of the results and a provision to discuss the results with the author, and we have a small research-topic oriented learning management system.

With the cost of computers and Internet accessibility coming down fast, coupled with the increasing speed of the Internet, applets such as these have great potential in spreading the reach and scope of on-line-teaching, specifically of experiment based science topics. With the number of students pursuing higher education in science expected to leapfrog in the years ahead, small, cost-effective initiatives as this, would go a long way to overcome the shortage of manpower and infrastructure, especially in developing countries like ours. Students would be encouraged to overcome their inhibitions regarding asking questions to the teacher in the class. They would be more inclined to try and find the answers themselves through the use of such applets. They can also post their queries, even anonymously, and receive the answers from the teacher through the applet. While it would be imprudent to suggest that such applets can one day make the role of the teacher redundant, they will no doubt help complement the traditional teaching methodologies which are followed today. The most productive scenario would be one in which both are used concurrently, helping one to feed from the other. Learning would indeed be a less-strenuous and more enjoyable process. Successful implementation of the ‘Right to Education’ Act will require the encouragement and adoption of ‘E-Learning’ initiatives of this kind.

ACKNOWLEDGMENT

The author thanks University Grants Commission (Eastern Regional Office) for financial support.
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Manuscript received 05 April 2010 (Revised 05 May 2010). This work was supported in part by the University Grants Commission (ERO) (No. F.PSW-034/07-08 (ERO)).

Published as submitted by the author.
Figure 1. A screen-shot of the ‘Experimenting with a parallel resonant circuit’ applet, showing the circuit, relevant theory, controls and the full-wave rectifier output waveform along with its Fourier components.

Fourier series for $v_m(t)$:

$$v_m(t) = \frac{V_0}{\pi} + \frac{V_0}{2} \sin(\omega t) - \frac{2V_0}{\pi} \left( \frac{1}{1^2} \cos(2\omega t) + \frac{1}{3^2} \cos(4\omega t) + \ldots \right)$$

Full wave rectifier

$$v_m(t) = \begin{cases} +V_0 \sin(\omega t) & \text{for } 0 < t < \frac{T}{2} \\ -V_0 \sin(\omega t) & \text{for } \frac{T}{2} < t < T \end{cases}$$

Fourier series for $v_m(t)$:

$$v_m(t) = \frac{2}{\pi} - \frac{4}{\pi} \sum_{n=2,4,6,\ldots} \frac{\sin(n\omega t)}{n^2 - 1}$$
Figure 2. A screen-shot of the ‘Experimenting with a parallel resonant circuit’ applet, showing the output waveform and its constituent harmonics when the input signal frequency is close to one-fourth of the resonant frequency.
Figure 3. A screen-shot of the ‘Experimenting with a parallel resonant circuit’ applet, showing the output waveform and its constituent harmonics when the input signal frequency is a little greater than one-fourth of the resonant frequency as also the frequency-spectrum.
An interactive diode applet

* Static and dynamic characteristics:

Have a look at the bottom-middle panel. The value ($V_d$) of the power supply is varying. The changes in the resulting values of the diode voltage ($V_d$) and diode current ($I$) for the fixed value of $R$ are being reflected in the meter readings. The data is also being tabulated in the top-right panel. The graphs for the $V_d$ vs $I$ (static curve) and $V_d$ vs $I$ (dynamic curve) are plotted simultaneously in the top-middle panel. The numerical technique employed is presented in the bottom-right panel.

Figure 4. A screen-shot of the ‘Experimenting with the p-n diode’ applet, showing a demo on how to obtain the volt-ampere characteristics.
Figure 5. A screen-shot of the ‘Experimenting with the p-n diode’ applet, showing how one may study temperature dependence of the diode characteristic curve.
Figure 6. A screen-shot of the ‘Experimenting with the p-n diode’ applet, showing a demo on how to obtain the ac resistance from the volt-ampere characteristic.

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Diode resistances

When a diode is subjected to a dc input voltage, a fixed current results and we get a fixed operating point or Q (quiescent) point on the static diode characteristic curve. The resistance of the diode at this Q point is called the dc or static resistance and is given by

$$R_d = \frac{V_d}{I_d}$$

where $V_d$ and $I_d$ are the diode-voltage and diode-current values at this operating point.
Figure 7. A screen-shot of the bottom-right panel of the ‘Experimenting with the p-n diode’ applet, showing the links to the relevant theory and other features.

Figure 8. A screen-shot of the quiz sub-panel housed inside the bottom-right panel of the ‘Experimenting with the p-n diode’ applet.
Electron-density-based dynamics of select many-electron systems under intense laser fields

Figure 9. A screen-shot of the ‘Presenting the findings related to a research topic’ applet, showing the relevant theory, the option-boxes, the surface and contour plots of the electron density obtained for the system under question and also links to, among other things, the relevant theory and computational methodology employed.

Illustration through an applet. Copyright: Abhijit Poddar

Quantum Fluid Density Functional Theory (QFDFT) enables one to obtain the ground state energies of the full spectrum of noble gas atoms in an appropriately scaled cylindrical coordinate system, through the use of a single generalized non-linear Schrodinger equation [Poddar and Deb, Journal of Physics A, 40, 2007, pgs 5981-5993]. We can make use of the same equation and the algorithm to study electron-density-dependent-phenomena in the attosecond...