A 3D Tool For the Support of the Traditional Teaching of Electric Circuits

Breno Serique Meiguins, Bianchi Serique Meiguins, Luiz Affonso Guedes and Schubert Ribeiro de Carvalho

Abstract ? **The objective of this article is to introduce the Virtual Laboratory for Electronic Experiments (VLEE) that is a virtual reality environment for the simulation of electronic experiments. The virtual world of VLEE was inspired by's electronic engineering laboratories from the Universidade Federal do Pará (UFPA, Federal University of Pará). It is possible to make simulations of electronic circuits locally or remotely using capacitor, inductor and resistor components. To develop this prototype, the following languages and tools were used: *Virtual Reality Modeling Language* (VRML*)*, *External Authoring Interface* (EAI), JAVA language and SPICE (*Simulation Program with Integrated Circuit Emphasis*).**

Keywords ? **Teaching in Engineering; Distance Learning and Virtual Reality.**

I. INTRODUCTION

When one uses concepts of Virtual Reality (VR) for the construction of educational environments, one realizes that VR has the potential to change the way people learn by allowing the learners to explore the environments, processes or objects that are inserted in the study context through the manipulation and the virtual analysis of the purpose of the study and by getting at each move they make a feedback from it

The Virtual Laboratory for Electronic Experiments (VLEE) was conceived with the purpose of applying to Education the characteristics provided by the VR. The VLEE is a virtual environment that enables the student to create electric circuits in a three-dimensional manner and then make a simulation of them obtaining results such as current and tension simulations in the components of the created circuit. The simulations can be made locally or remotely via Internet by extending such possible uses of VR to Distance Learning.

This article is intended to present one of the VLEE prototypes that aims at incrementing realism in the use of the computer as an instructional tool by providing a three-dimensional interface and thus making it easier for the student to learn.

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The electric circuits of laboratory experiments are assembled on a special platform, whose name is *protoboard*, like in the real world in which the use of components such as resistors, power supplies, inductors, capacitors etc is possible which can be analyzed with different frequencies under continuous or alternating currents.

The VLEE uses *Virtual Reality Modeling Language* (VRML) (for constructing virtual environments), Java language (to allow for simulation through computer networks) and *External Authoring Interface* (EAI), as a proposal to increase interactivity and information exchange between the user and the virtual environment and also the simulator of electric circuits, called PSPICE *(Simulation Program with Integrated Circuit Emphasis)*.

This work generally involves concepts on applications of Virtual Reality and Education and focus on the integration between VRML and JAVA as well to construct virtual environments for education. And it is organized as follows: in section 2, concepts on Virtual Reality are presented. In section 3 arguments for the use of Virtual Reality in Education. In section 4, the traditional way of teaching Electrical Engineering is discussed. In section 5, VLEE, its features and ways of functioning are presented. Finally, in section 6, some considerations on the development of the project and future works are discussed.

II. VIRTUAL REALITY

When one considers virtual environments or Virtual Reality Systems (VRSs), one tends to think of a person wearing an HDM (head-mounted display) completely immersed in an environment generated by a computer. This occurs in a small part of the large array of VRSs, showing a method of information delivery that is purely immersive and of great realism to the user. However, we'd rather take the term Virtual Reality in a broader context such as the Non-immersive VRSs, which is the case in this proposal. Non-Immersive Virtual Reality is about images generated directly on the screen and does not require the use of unconventional peripherals. Thus, you have more realistic and exciting possibilities for the application in instructional situations.

The interface with VR involves a highly interactive three-dimensional control of computer processes. As he/she walks into a virtual environment (3D interface) of the applications, the user views, manipulates and explores real-time data by using his senses [1][5]. The great advantage of this kind of interface is that the user can use the intuition he obtained in the real world to manipulate the virtual environment.

III. VIRTUAL REALITY: CONTRIBUTIONS FOR EDUCATION AND THE LEARNING PROCESS

Virtual Reality can be a valuable tool for education becoming one more facilitating factor in the learning process. According to Pantelides [7] there are several reasons for using Virtual Reality in education, such as, greater student motivation, greater interaction between the learner and the learning contents and greater possibilities to analyze the object of the study. According to Stuart & Thomas [8], the VR applications can provide learners with different capabilities, such as how to interact with people, objects and worlds in an unrealistic manner, to make experiment simulations whose realizations in the real world are expensive and/or dangerous and to enable handicapped people to do activities that would not be possible in the real world. Besides all these VR positive factors, it also requires low data transfer rate between remote users because, unlike multimedia systems, it does not require continuous data transfer, it only requires commands for manipulation and synchronization of virtual worlds [3]. As one can see, all these VR characteristics are very welcome in the Distance Learning field.

III. TRADITIONAL TEACHING OF ENGINEERING AND THE USE OF VIRTUAL REALITY

It is known that in the Electrical Engineering course of any university the demand for laboratories to form future professionals of the area is very important and this is equally true at the Universidade Federal do Pará (Federal University of Pará). Even though there are enough laboratories to support the course's table of subjects at UFPA, maintenance and unaccompanied access to them is difficult. To discuss such reasons is not part of the scope of this study; however, what really matters to us is to verify such facts obtained in interviews between teachers and students of the course so that one can propose viable alternatives to solve or mitigate these problems and thus increase the quality of the teaching and learning processes in the Electrical Engineering Course.

In this interview, many teachers of the program found that funds were a limitative factor for the creation and maintenance of laboratories. Some not less important problems mentioned were equipment and components to be replaced, accidents, surge or power cutoff in the network, size of the class for each laboratory, equipment and component defects, unavailable online access for the follow-up of an experiment and impossibility for the student to come to the laboratory sessions. All these items can interfere in the course of the lab sessions. We believe that these problems are to a large extent common to many electrical engineering courses in this country.

Even if there are problems with the traditional teaching of electrical engineering, it also has many advantages. We can say that this is still the best teaching alternative for the reasons that follow:

?? access to the available technology in the labs;

?? familiarity with the different kinds of problems;

?? possibility to perform many tests in electronic equipment and components and

?? familiarity with the different kinds of equipment and components present in the market.

Now that the difficulties in the traditional electrical engineering teaching system are known, we suggest the use of VR as an auxiliary for laboratory teaching so that the following goals are reached:

?? **making knowledge available, easily and equally accessible to everyone:** With the use of VR, one could create virtual laboratories that would be made available through the Internet; so that students could do their experiments at their own pace and so that they could better assimilate the experiments' contents and objectives.

?? **enhancing the interface between man and the machines:** some laboratories can only use math applications with some 2D graphics for experiments. With this the student has no idea what the equipment is really like. The use of VR can mitigate this problem.

?? **making cultural interchange between people possible:** the utilization of VR in Distance Learning would make possible for people from different teaching institutions to interact and discuss about problems, to work together or simply to attend classes in a 3D virtual classroom. We could then check how different people from different institutions approach the same problems.

V. A PROPOSAL FOR THE INSTRUCTIONAL USE OF VIRTUAL REALITY FOR ELECTRICAL ENGINEERING

1) *Virtual Laboratory for Electronic Experiments*

The proposal is to use Virtual Reality as a more natural interface between student and computer for the simulation of electric circuits with passive components, i.e., by using resis tors, capacitors and inductors

. However, these experiments should not be restricted to electric circuits, and we called all these experiments Virtual Laboratory for Electronic Experiments (VLEE).

Because of the difficulties found in the teaching/learning processes in the traditional Electrical Engineering course, we are proposing the use of systems based on VR in order to either minimize such problems or solve them completely, always making it clear that VR must be used as a tool to help in the classroom teaching and not as a substitute to it.

The VLEE project has the following objectives:

?? to make knowledge available to be learned and for complementary reviews of the subjects involved;

?? to provide more time for practical experiments taking into account the student's own pace;

?? to make the learning process easier through an interactive interface that uses prior knowledge obtained in the real world;

?? to reduce implementation costs for the labs, at least for the most common tasks and for the early stages of the learning;

?? to evaluate the VR potential for education;

?? to enable an easy update of the whole group of virtual laboratory experiments and

?? to evaluate the potentiality and difficulties of VRML x Java integration.

2) Technological Aspects

To develop a prototype for this proposal's case study, two languages were used: VRML (*Virtual Reality Modeling Language)* [9], language used for the modeling and for the construction of 3D virtual environments and JAVA [2]. Besides, an interface called *External Authoring Interface* [6] is needed to allow communication between JAVA and VRML, in order to increase interaction between the user and the virtual environment by the means of softwares, called *applets*, which can be executed on a HTML (*HyperText Markup Language*) page. Another software was used as well, whose functionality is to simulate the operation of an electric circuit without having to construct it, called SPICE (*Simulation Program with Integrated Circuit Emphasis*) [4] (Fig. 1).

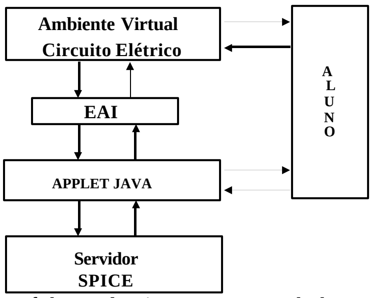

Fig. 1: Overview of the student's interaction with the parts in the VLEE.

3) The 3D Virtual Environment

Thinking of a better adaptation of the student to the created virtual environment, the UFPA's Electrical Engineering lab building was three-dimensionally modeled (Fig. 2) so that the student could feel as close to reality as possible and could use his/her prior knowledge obtained in the real world. The student can walk all over the building and choose which laboratory to get in to do his/her experiments (Fig. 3). Each laboratory is related to a different activity and is located in the virtual world exactly the same way as it is located in the real world. With a simple mouse click on the lab doors, other virtual environments will appear (Fig. 4 e Fig. 5), which are the interior part of these labs and each laboratory, in turn, will open up other worlds which are the experiments themselves.

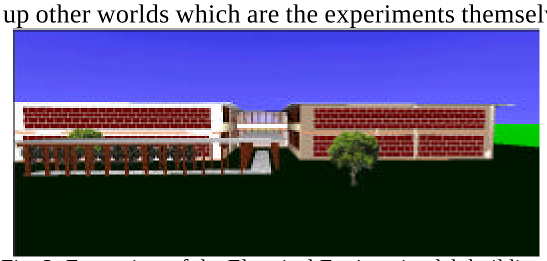
Fig. 2: Front view of the Electrical Engineering lab building.

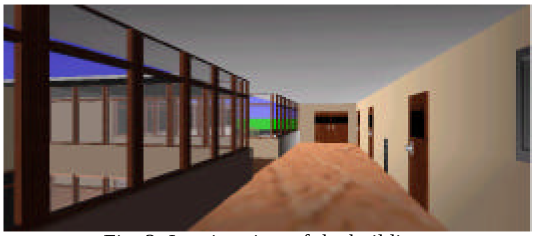
Fig. 3: Interior view of the building.

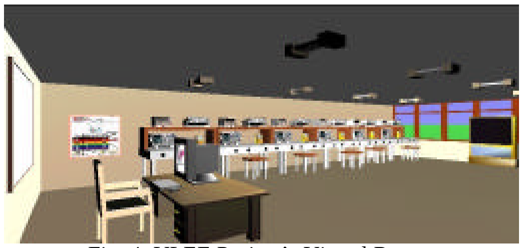
Fig. 4: VLEE Project's Virtual Room.


Fig. 5: Another view of the VLEE's virtual room.

The elements in the virtual room can be manipulated. That is, they can take you to another place in the virtual world (experiments) by the *click* of the *mouse* or by the means of a proximity detector, and also access a local or remote URL (*Uniform Resource Locator*) (class notes and references indicated by the teacher), start events (educational videos), change the characteristics of objects such as location, transparency, color, scale etc. Thus, the student can find everything he/she needs to perform his/her experiment and can also model the room the way he/she wishes.

4) Communication Architecture

Even though the VLEE is still a one-user virtual environment, it allows many instances to be executed simultaneously. That is, there is a possibility that two or more students are simulating their circuits at the same time without interfering with one with the other. The client-server model is used and implemented through programming in Java using *threads* and *sockets*, in which each *thread* manages a connection and each connection is made by a pair of *sockets* that links the student's computer (client) to the server where the VLEE components are installed (Fig. 6).

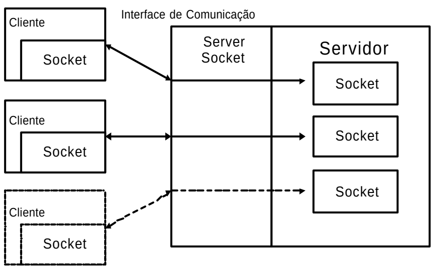

Fig. 6: The VLEE's communication architecture.

5) *Prototype*

Virtual experiments are easy to create, the user is totally free to assemble and visualize the created circuit in them. And the simulation of electric circuits is made with a tool, called PSPICE, an electric circuit simulator specifically for their calculations.

The prototype's interface is made up of two main parts: the first one where the virtual component is visualized and manipulated (Fig. 7), and the second one is where the parameters for component creation are inserted (Fig. 8), a sort of form with text boxes and buttons. Both the virtual environment and the form mentioned above are part of a Web page so the prototype can be accessed from any computer that has access to the Internet.

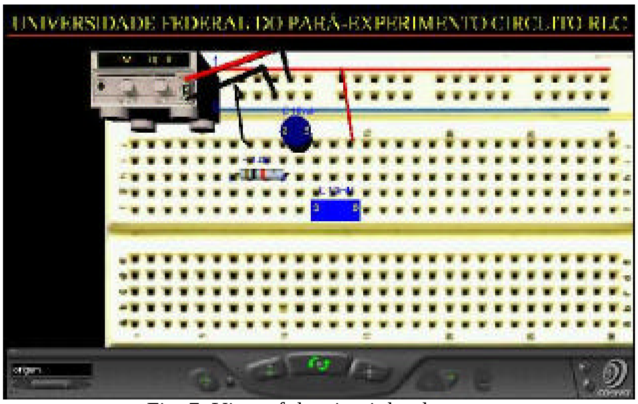

Fig. 7: View of the circuit by the user.

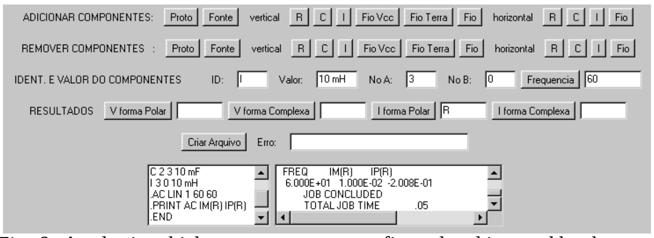

Fig. 8: Applet in which components are configured and inserted by the user.

Once the virtual circuit creation is completed, the next step is to make a simulation of the created circuit presenting its results on the applet so that students can analyze them (Fig. 8).

6) *Example of Assembly and Calculation of a Circuit (RLC in Series)*

In this section, a sequence of commented figures is shown on how to create and simulate an electric circuit for a better demonstration of the VLEE project's features. The circuit will have a power supply, a resistor, a capacitor and an inductor, characteristics of a classical RLC circuit in series. The V identification power supply will have an amplitude of 10.00 volts and 60Hz power frequence, the resistor will have 1.0 ? R value, the capacitor will have 10mF C value and the inductor L 10mH. All assembled on a Protoboard. Here are the steps:

?? ***Insertion of the Protoboard***: the protoboard will be inserted in the virtual environment (Fig. 9) only with a simple click on the Proto button, see Fig. 10.

?? **Insertion of the power supply:** the V power supply will be inserted between nodes 0 and 1 (Fig. 9). The data to have the power supply inserted into the virtual environment can be seen in Fig. 10. Note that at the same time the components are inserted into the virtual environment, the *netlist* (input file to PSPICE for circuit simulation) is being created and visualized on the *applet* (Fig. 10).

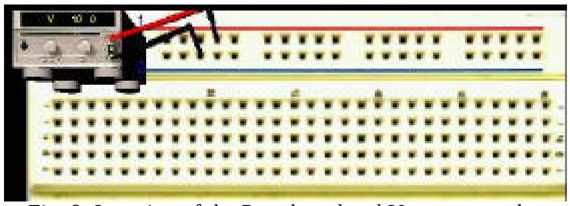

Fig. 9: Insertion of the Protoboard and V power supply.

Fig. 10: A*pplet's* instance, insertion of the power supply.

?? **Insertion of resistor R:** the components are always inserted into the virtual environment on the coordinates (0,0,0). The resistor R will be inserted between nodes 1 and 2. Once it is inserted, just drag it in a way that node 1 is electrically connected with the power supply's node 1 on the *protoboard* (Fig. 11). One can observe that a code of colors is assigned to the resistor for specific resistance values. The procedure for resistor insertion is similar to the one of the other components: capacitor and the inductor. The *netlist* is updated in Fig. 12.

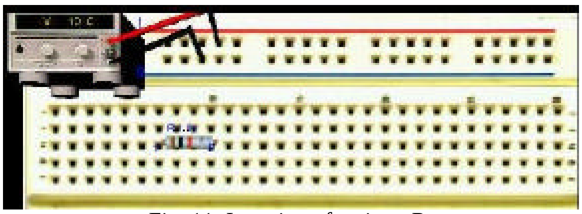

Fig. 11: Insertion of resistor R.

Fig. 12: A*pplet's* instance, insertion of resistor R.

?? **Insertion of Capacitor C and Inductor L:** capacitor C will be inserted between the nodes 2 and 3 and Inductor L will be also inserted between the nodes 3 and 0 as well, once all the components are in series (Fig. 13). The *netlist* is updated in Fig. 14 with the new components.

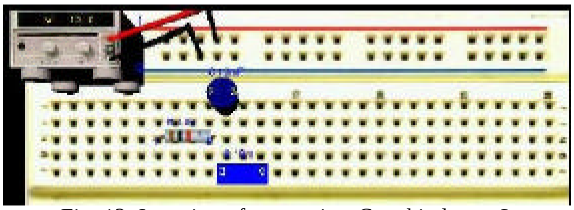

Fig. 13: Insertion of a capacitor C and inductor L

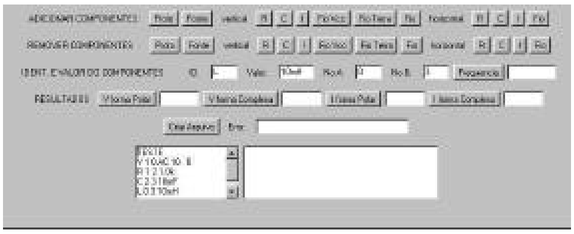

Fig. 14: A*pplet's* instance, insertion of capacitor C and Inductor L.

?? **Insertion of cables:** cables are inserted to electrically shut the circuit on the *protoboard*. There will be two cables in total (Fig. 15). The insertion of cables into a virtual environment does not change the *netlist*.

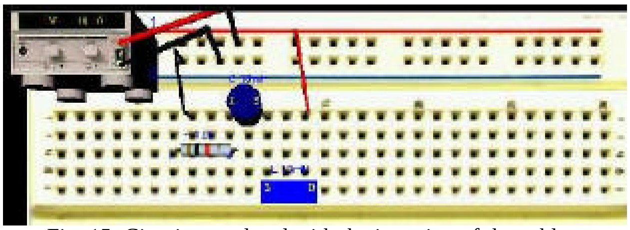

Fig. 15: Circuit completed with the insertion of the cables.

?? **Circuit Calculation:** To calculate the circuit, it is necessary primarily to make use of the "Freqüência" (Frequence) button, in our case we will use 60Hz (the standard power frequence in Brazil). After that, the "I Forma Polar" button is used (Fig. 16) because one wishes to know the result of the current that goes over the resistor that is the circuit's total current. Finally, the "Criar Arquivo" (Create File) button is used. This button creates the input file for the SPICE, the *netlist*, and sends it to the server to be processed by the SPICE (Figure 16). Once it is processed, the output file is sent to the *applet* for student analysis or possible for the update of any component in the environment such as the ammeter or the voltmeter (Figure 17).

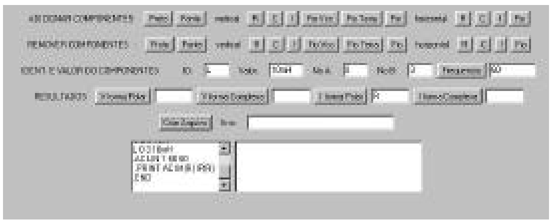

Fig. 16: Netlist with information about the frequence and the kind of response chosen for analysis.

Fig. 17: Applet showing the result of the circuit simulation

VI. Final Considerations

In this paper, the VLEE project (Virtual Laboratory for Electronic Experiments) is shown in its current stage. The VLEE aims at improving or solidifying concepts the students learned in the traditional electric circuit lab sessions. To help with this goal, the VLEE's virtual environment was created to be as close to the real environment as possible to help the user interact. However, we believe that, with easily accessible online material, electronic books and exercises, such features will make VLEE a promising auxiliary tool in the teaching of electrical engineering.

In future works we intend to develop an electric circuit simulator written in JAVA, so SPICE will no longer be needed. This will make VLEE totally portable to the several existing computer platforms and also make future updates much easier. Finally, we intend to go further investigating the use of the VLEE so we can evaluate in practical terms how beneficial its use can be.

References

[1] - BURDEA. G.; COIFFET, P. **Virtual Reality Technology**. John Wiley & Sons, 1994.

[2] - CORNELL, G. **Core Java**. Makron Books. 1997

[3] - DIZERO, W. J. et al. **Professor Virtual: A Realidade Virtual como Suporte ao Ensino de Informática à Distância**. Anais do XVIII do SBC, Belo Horizonte/BH. 1998. pp 614-623.

[4] - FENICAL, L. H. **PSpice: A Tutorial**. Regents/Prentice Hall. 1995

[5] - KIRNER, C. **Sistemas de Realidade Virtual**. GRV (UFSCar). Disponível: . http://www.dc.ufscar.br/~grv/tutrv.htm. [janeiro 1998]

[6] - MARRIN, C.; et al. **EAI specification.** Available: http://vrml.sgi.com/moving-worlds/spec/ExternalInterface.html 1999

[7] - PANTELIDES, V. S. **Reasons to Use Virtual Reality in Education**. 1995. Available: http://eastnet.educ.ecu.edu/vr/reas.html [1998 july]

[8] - STUART, R., Thomas, J. C. **The Implications of Education in Cyberspace.** Multimedia Review, Summer, 2, pp. 17-27, 1991.

[9] - Web3D Consortium. **VRML97 Specification.** Disponível, URL: http://www.vrml.org/techicalinfo/specifications/vrml97/index.html.