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Toward a Virtual Lab. for electronics virtual experiments

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Abstract:

This paper presents a virtual reality application dedicated to electronics virtual experiments: circuit design and simulation. The virtual environment offers virtual components (resistors, capacitors and transistors) and virtual electronics equipments (generators and oscilloscopes) described in a standard Virtual Reality Modeling Language (VRML) format. Students can choose components and build a circuit. A remote simulation of the circuit is achieved using the SPICE program that is a general-purpose circuit simulation program for non-linear dc, non-linear transient, and linear ac analyses. Simulation results are displayed on virtual electronics equipments that are involved into the simulation. The implementation is based on VRML and Java as languages and Cortona VRML plug-in from ParallelGraphics.

It is available on the Internet at the following URL:
<http://intranet.iseb.fr:85/vlab/monde.wrl>

Key Words:

Virtual Environments, Virtual Reality Modeling Language, Java, Electronics Simulation, Electronics virtual experiments, Web-based Training.

1. INTRODUCTION

Until now, we have nearly 200 students using laptops for various activities. By the end of June 2004, we made a survey in order to collect information about students' point of view on their laptop and our e-Campus.

One of the questions was: "What are your main uses of your laptop?" Answers are shown in Fig. 1.

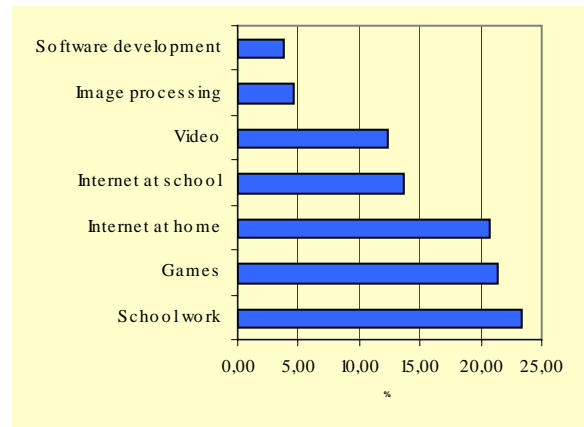


Fig. 1. Student's laptop uses (%)

It is not surprising that schoolwork is the first use (23.37%). But the practice of games (21.41%) is very close to schoolwork. Only a few students are using their computer for software development (3.85%). This is due to the fact that our school is mainly a Graduate School of Electronics.

Commercial games have created a form of learning that students are very familiar with [1]. Game based learning is a nice way to involve students in the process of learning.

According to these facts, we have decided to pay interest into the development of game-like pedagogical tools in order to improve creativity and teamwork.

The main goal of our project is to develop a virtual world that a group of students will share in order to achieve some electronics virtual experiments together.

Such a virtual world would implement:

- Virtual components and virtual electronics equipments,
- Intelligent pedagogical agents dedicated to the monitoring of students activities.

In this paper, we focus on the development of the virtual world dedicated to electronics experiments: circuit design and simulation. This development is an early first step toward a multi-user distributed application that would involve a group of students into a common task.

The first part of the paper deals with a brief survey of existing pedagogical materials dedicated to electronics simulations. In the second part we describe the virtual world that has been developed: virtual components and virtual electronics equipments. The third part of the paper gives details about some technical aspects of our development and especially the simulation, which is based on the SPICE program.

2. QUICK SURVEY

A quick survey on existing pedagogical materials points out that the main tools dedicated to the training in electronics are generally 2D software.

Two examples of projects, which are providing such pedagogical materials, are:

- INEIT-MUCON [2] - Innovation for Education in Information Technology through Multimedia and Communication Networks (1996-2000)
- THEIERE [3] - Thematic Harmonisation in Electrical and Information Engineering in Europe (2000-2003)

They are targeting families of applications. They are not really “game-like”. They rarely enable teamwork. Sometimes, they have multimedia components and fit with distance learning requirements but generally there is a lack of user interactivity compare to virtual reality applications.

In other cases, the target is to share and use lab equipments through the network, for examples:

- Microelectronics WebLab [4]

- Virtual Laboratories In Electronic Engineering Education [5]

None of these applications provide immersive environments where students are involved as actors in order to design and simulate electronics circuits.

3. VIRTUAL WORLD DESCRIPTION

The implementation of the virtual world is based on VRML (Virtual Reality Modeling Language) [6]. Users may view 3D contents with a Web Browser and a VRML plug-in. The actual implementation is using Cortona VRML plug-in from ParallelGraphics.

3.1 Virtual components

Until now, we have implemented 3 different types of components (Fig. 2.), which are resistors, capacitors, and transistors.

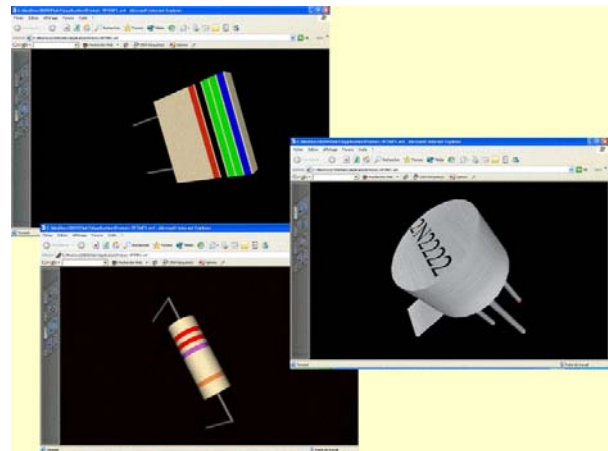


Fig. 2. Basic components

Students can choose a value for resistors or capacitors by selecting the right colours on the components according to colour codes. Two types of transistors are available: NPN and PNP, respectively 2N222 and 2N2907.

3.2 Designing a circuit

Components are inserted into the virtual world when students click on the corresponding icon (Fig. 3.).

Students can move (or rotate) components by means of virtual axis that represent the directions of the movement.

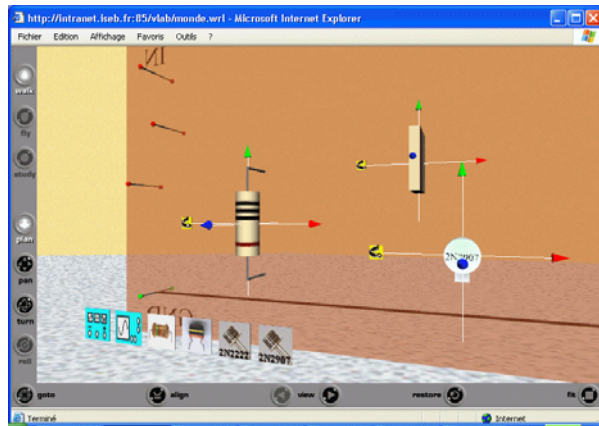


Fig. 3 Moving components

After they have put components on the virtual board, students can build the circuit by clicking on components' pins behind the virtual board (Fig. 4.). A link is created in the virtual world. It represents a connection between components. Such a link can't be deleted. That means that the component has been virtually welded on the virtual board. Components can't be moved anymore.



Fig. 4. Drawing the circuit

3.3 Virtual electronics equipments and simulation

Two types of virtual electronics equipments are available today: generators and oscilloscopes.

Generators (Fig. 5.) enable students to set up a signal in terms of frequency, voltage and waveform. This signal will be applied to the circuit on the inputs selected by the student.

A new link is created into the virtual world when a student clicks on the output of a generator and a components' pin.

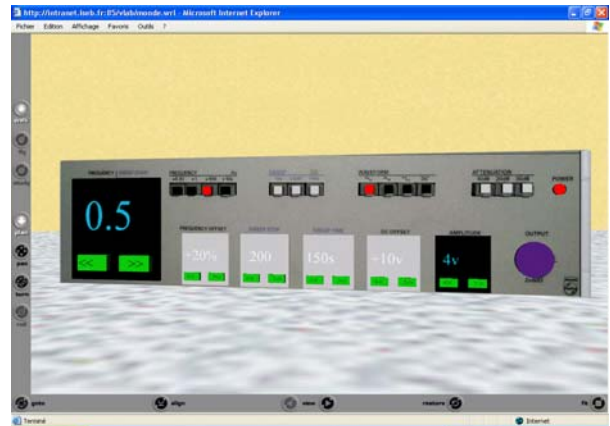


Fig. 5. Generator

Oscilloscopes (Fig. 6.) enable students to view circuits 'outputs. That is to say: "simulation results". Two channels are available. Students can adjust voltage and/or time scale.

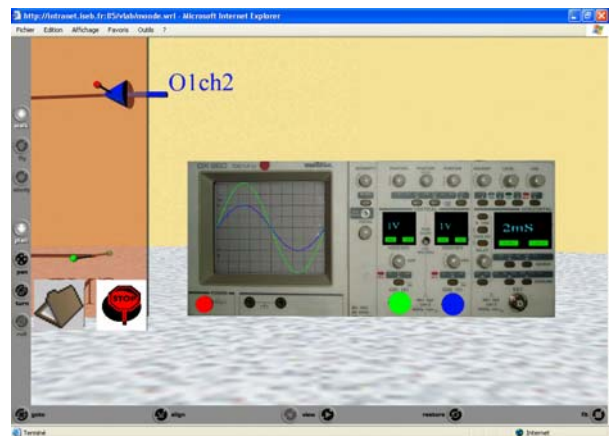


Fig. 6. Oscilloscope

Once more, a link is created into the virtual world when a student clicks on a channel input and a components' pin.

We have introduced special components (pads) on the virtual board in order to make easier connections between virtual electronics equipments and the circuit.

3.4 Managing files

A basic file manager has been implemented in order to save on going work (Fig. 7.).

Links, components values and locations are stored in a file on a server. They can be loaded at anytime.

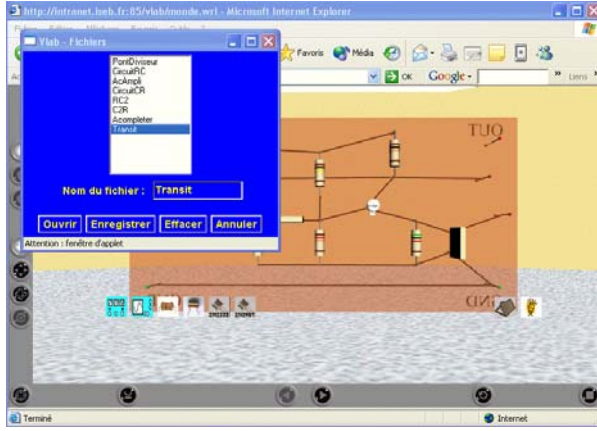


Fig. 7. File manager interface

4. TECHNICAL POINT OF VIEW

The Virtual Lab. software architecture (Fig. 8.) on client side implements a Java application.

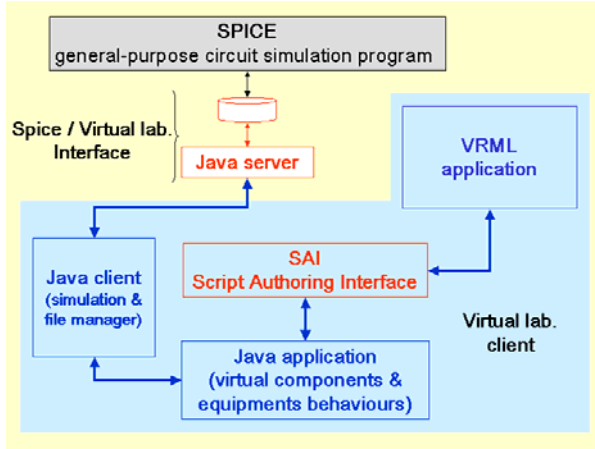


Fig. 8. Virtual Lab. software architecture

This application manages virtual components' local behaviour and computes data for simulation. Java classes (Fig. 9.) manage user interactions within the virtual world according to VRML specifications [7].

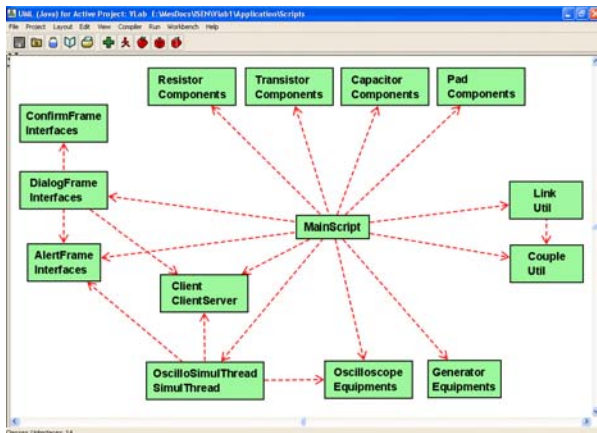


Fig. 9. Virtual Lab. Java objects and packages

4.1 From design to simulation: topology

When a student selects components pins in order to draw the circuit we create a link L_i by means of a set of two couple:

$$L_i = ((N_a, P_a), (N_b, P_b))$$

where N_j is the component name and P_j describes the component pin. All these links give a representation of the circuit topology. The next step, prior to simulation, is to compute equipotential nodes. An equipotential node is a set of couples where all pins are sharing the same connection.

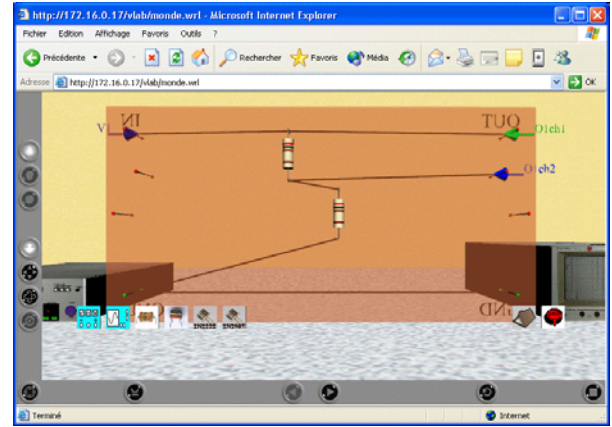


Fig. 10. Circuit example

For example, according to the previous circuit (Fig. 10.) we obtain the following set of nodes:

NODE 0: (P3,1) (P7,1) (V1,1) (O1,3) (R1,2)
NODE 1: (O1,1) (P0,1) (R0,1) (P4,1) (V1,2)
NODE 2: (O1,2) (P1,1) (R0,2) (R1,1)

Where P_i , V_i , O_i and R_i respectively represent Pads, Generators, Oscilloscopes and Resistors. This set of nodes is used to create the netlist of the circuit.

4.2 From simulation to results

The simulation is implemented by means of the SPICE software [8]. SPICE is a general-purpose circuit simulation program for non-linear dc, non-linear transient, and linear ac analyses. In the context of this project simulation runs on a server according to clients' requests.

SPICE has already been used remotely through the web [9] [10] but in our case the virtual environment acts as an authoring tool generating a description of the circuit being simulated. This description is written in SPICE 'language'.

Simulation results are displayed on virtual electronics equipments that are involved into the simulation.

For example, when a student decides to run a simulation of the previous circuit (Fig. 10.) a text file is generated according to SPICE syntax:

```
#Vlab Circuit - ISEN Brest
.include VlabData.cir
R0 1 2 20.0
R1 2 0 20.0
V1 1 0 SIN(0 4.0 50.0 0 0)
.tran 0.2ms 20.0ms
.save V(1) V(2)
.end
```

This file contains the netlist of the circuit and the directives for the simulations. It includes a reference to a special file *VlabData.cir* that contains models definitions. For example:

```
.model m2N2222 npn is=19f bf=150 vaf=100
ikf=.18 ise=50p ne=2.5 br=7.5 var=6.4
ikr=12m isc=8.7p nc=1.2 rb=50 re=0.4
rc=0.4 cje=26p tf=0.5n cjc=11p tr=7n
xtb=1.5 kf=0.032f af=1
```

describes a Bipolar Junction Transistors named m2N2222.

The text file is sent from the client to the server. The server runs the SPICE program. Results are written in a text file and sent back to the client.

According to our example, the client will receive the following data:

```
Title: #Vlab Circuit - ISEN Brest
Date: Mon Feb 28 14:54:47 2005
Plotname: Transient Analysis
Flags: real
No. Variables: 3
No. Points: 59

Variables:
  0    time    time
  1    V(1)    voltage
  2    V(2)    voltage

Values:
0    0.0000000000000000e+00
    0.0000000000000000e+00
    0.0000000000000000e+00

1    2.0000000000000000e-06
    2.513273957505029e-03
    1.256636978752515e-03
...
```

On client side, values are extracted from the text file. They are used to draw the result on the screen of the virtual oscilloscope according to voltage and time scale (Fig. 6.).

As time scale may be different from one oscilloscope to another, we have decided to run as much simulation as we have virtual equipments involved into the experiment. According to a classical client-server architecture there is one thread running per equipment involved into the simulation (Fig. 9.).

5. CONCLUSIONS AND FUTURE WORKS

This first prototype demonstrates the feasibility to plug an external simulation program such as SPICE to a virtual world dedicated to electronics circuit simulations.

First experiments with students point out that it is necessary to change the behaviour of the user interface in order to run a simulation. For example, if generators or components values are changed after a simulation has been achieved, the drawing on the screen of the oscilloscope is not updated.

In the immediate future, we will introduce new components such as inductors, diodes, MOS transistors, operational amplifiers and new virtual electronics equipments such as a spectral analyser. This will enable us to enhance types of circuits that would be designed.

We are also working on a distributed version of Virtual Lab. The distributed implementation will be based on DeepMatrix [11] as environment server. We have already developed such an implementation in a previous project [12] [13]. This distributed version will enable teamwork and will also integrate pedagogical agents and tutor behaviour [14].

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