A Multimodal Environment for Cooperative and Transnational Training Activities

Jean-Pierre Gerval, Bassem Fennani, Habib Hamam, Mihai Polceanu, Ammar Assoum, Dorin-Mircea Popovici, Yann Le Ru, Hùng Ngô, Valeriu Dulgheru

A Multimodal Environment for Cooperative and Transnational Training Activities

Authors:

Mihai Polceanu, OVIDIUS University, 124 Mamaia Bd, 900527, Constanta, Romania, polceanum@gmail.com

Ammar Assoum, Lebanese University, Faculty of Science, Section 3, Laboratory LaMA-Liban P.O. Box 826, Tripoli, Lebanon, a.assoum@ul.edu.lb

Jean-Pierre Gerval, Institut Supérieur de l'Electronique et du Numérique – Brest, 20 rue Cuirassé Bretagne, CS 42807, 29228 BREST cedex 2, France, jean-pierre.gerval@isen.fr

Dorin-Mircea Popovici, OVIDIUS University, 124 Mamaia Bd, 900527, Constanta, Romania, dmpopovici@univ-ovidius.ro

Bassem Fennani, Moncton University, 165 av. Massey, Moncton (New-Brunswick) E1A 3E9, Canada, bassem.fennani@gmail.com

Yann Le Ru, Institut Supérieur de l'Electronique et du Numérique – Brest, 20 rue Cuirassé Bretagne, CS 42807, 29228 BREST cedex 2, France, yann.le-ru@isen.fr

Hùng Ngô, Viettronics Technology College, No 118 Quartier de Catbi , Arrondissement de Hai An Haiphong, Vietnam, hungngohn@gmail.com

Habib Hamam, Moncton University, 165 av. Massey, Moncton (New-Brunswick) E1A 3E9, Canada, habib.hamam@umoncton.ca

Valeriu Dulgheru, Technical University of Moldova, 168 Stefan cel Mare Blvd, Chisinau, MD-2004, Moldova, dulgheru@mail.utm.md

Abstract — *This paper deals with a project that aims at improving students' engineering skills especially when the actors of the project, the tasks to be achieved and the knowledge, are distributed between several different countries. The goal is to set up a digital environment that is capable of hosting distributed and cooperative practical activities for groups of students from different universities and different countries working together on the same activities. In terms of learner's behaviour, we aim at increasing motivation, minimizing passivity, stimulating group work and promoting cooperation and interaction among the students. Besides, at the level of academia, we aim at simplifying and rapidly transferring new knowledge as well as popularizing complex aspects and forbidding subjects by using new information technologies. In the following sections we lay out our implementation of the virtual classroom metaphor and we describe how we distributed our virtual worlds (X3D/VRML, JavaScript and AJAX). Further in the article we explain how we coped with the constant need for change and extensions in the context of distributed virtual environments: new objects to fill the ever-growing 3D world, and in the context of pedagogical activities: new activities, new topics, new methods, etc, by the means of a plug-in-like concept.*

Index Terms — *Distributed and Cooperative Practical Activities, Virtual Classroom, X3D/VRML world, JavaScript and Ajax3D*

1. INTRODUCTION

1.1 Context

The aspects that make the subject of this paper are the design and implementation of the EMULACTION (Environnement MULtimodal pour Activités Coopératives Transnationales de formatION / Multimodal Environment for Cooperative and Transnational Training Activities) project.

Most of higher educational establishments are developing their international relations in order to make students' mobility easier. But on a world-wide scale, which is often synonymous with international manpower or knowledge transfers, few establishments point out the real stakes enhancing the links between people and their activities to students.

This project aims to improve the students' practical skills through a distributed learning environment, with support for collaborative tasks and knowledge, which can be accessed by users from different countries. Our target is to develop a Digital Environment (Web-Based Portal) in order to enable distributed and cooperative practical activities: groups of students from different universities and different countries working together on the same activities.

Practical activities are designed using concept maps and therefore are translated into domain ontology [1]. SCORM (Sharable Content Object Reference Model) is used as a reference model for pedagogical material storage [2]. The first experiments that we will perform with EMULACTION implement practical activities in the following fields: Electronics, Digital Image Processing, Numerical Analysis, Computer Science and Signal Processing. Students from partner universities are involved in these experiments. Some of them are also involved into the design of the Digital Environment.

1.2 Digital Environment Architecture

According to the work to be carried out by students, a teacher configures one (or several) virtual room(s) where a group of students will have to work. To configure virtual rooms (Figure 1) means to:
1. define a teaching scenario: number of virtual rooms, assignment of activities to the rooms, order of the rooms according to activities, requirements to access the rooms (pre-requisite);
2. select communication tools that will be useful for students (chat, forum, blog, voice, video, whiteboard, etc.);
3. choose software tools to be used by the students according to the nature of the practical activities to carry out.
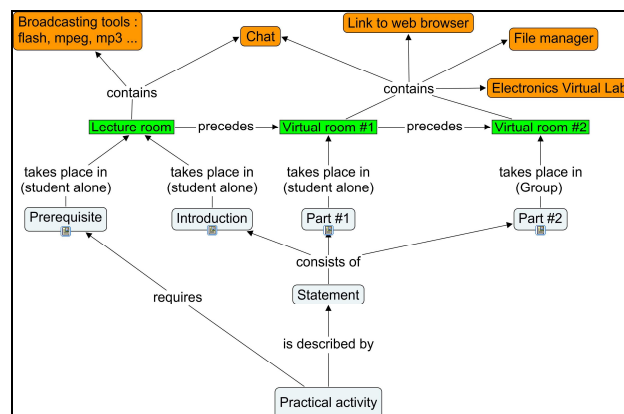

FIGURE 1
EXAMPLE OF CONCEPT MAP

In order to monitor their activities, teachers are able to interact with students in the virtual rooms. Students provide reports from their practical activities. Teachers have access to these documents in order to assess students' work (Figure 2).
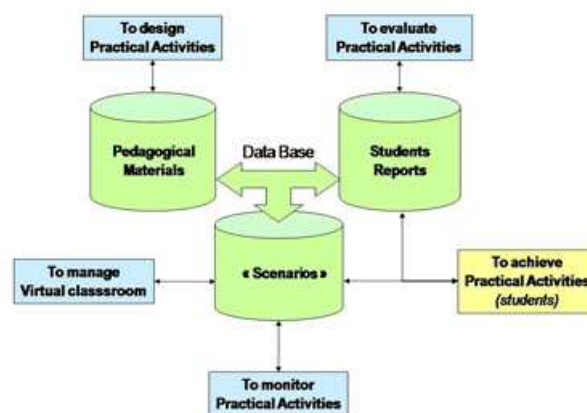

FIGURE 2
DIGITAL ENVIRONMENT ARCHITECTURE

The virtual room is a digital infrastructure that enables a cooperative learning process [3]. Our virtual rooms are developed in X3D (Extensible 3D). Users' interactions are managed through JavaScript and AJAX. On the server side we have a LAMP (Linux, Apache, MySQL, PHP) architecture.

In this paper we will focus on the design and the implementation of these virtual rooms as classrooms.

1.4 Designing practical activities

The web portal concept is used to enable the system's users to log into their account, manage their profile or view information and statistics about the courses and practical activities that are available, and helps to form an online community of interactive lessons.

Accounts can take two forms depending on whether the user is a teacher or a student. Student accounts provide a common management interface and also give the user the possibility of joining an instantiated classroom to attend courses and/or seminaries. Teacher accounts, as an addition to the student account, have the privilege of configuring and instantiating the classrooms that contain the necessary tools.

Besides the 3D environment and the chat module which is available for all members of the proposed online community, interaction between teachers and students is also made through a report system which allows documents to be shared and exchanged. These reports are used to evaluate students' tasks by the teachers, and to send results and feedback; they constitute the main method of assessment of this distributed application.

Teachers can design their own customized classroom by choosing from the available list of installed plug-ins (plug-ins are discussed later in this paper); this way a wide range of configurations can be achieved, depending on the purpose of the course or seminary.

2 VIRTUAL CLASSROOM METAPHOR

The learning environment we propose is a place where users can draw upon resources to make sense out of things and solve problems; here the learning may by fostered and supported [4]. A predominant metaphor is the "virtual classroom". According to [5], a virtual classroom is a location where students and teachers can communicate and collaborate on the basis of a "room metaphor" [6].

In such a classroom, it is considered that organizing the learners in teams may reduce most of the gaps between the individual knowledge by increasing communication and competition (in this order) [7]. In this way, competition becomes cooperation and increases the level of motivation. Hence, the complexity that may arise in "natural" ways even in the most "simple" subjects is a non-declared motivational factor when introduced gradually. Doing so, in the learning context, if the learners' needs are satisfied and their expectations are met, they will strive to develop their professional competences. They will be indirectly contributing to the development of the learning context (see Figure 3).

FIGURE 3-A
SAMPLE OF A SHARED VIRTUAL CLASSROOM

FIGURE 3-B
SAMPLE OF A SHARED VIRTUAL CLASSROOM

The potential of the proposed learning environment is significant because it gives its users a space to explore, determine goals and learn activities as attractive concepts.

Students can share the virtual environment in the same way they share the real one, and they naturally start to form small work teams in the virtual setup, based on the real environment configuration. Later, these teams evolve based on the complementary knowledge that the team members possess, in order to assure high-level of team performance. At this point, learning communities emerge [8]. Shared experiences, based on common projects and learning curricula, provide different but complementary perspectives to the subject of the lesson, depending on each individual.

3. DISTRIBUTING VIRTUAL WORLDS

In this section we try to explain why we used the online 3D content paradigm in the educational context, what software solutions we chose to achieve a viable system, and how we made the system extensible.

3.1 Using web3d technologies in education

Very often we were asked a simple but hard to answer question: "*Why are you using 3D for education instead of classical or multimedia approaches?*" In a discussion about Perkins' point of view about learning environment, expressed in [9], Wilson points out that if we simplify and pack instruction for consumption, the fullness of the subject can be bleached away, and so learning outside the context of its natural setting can also have the same affect [4]. Using 3D virtual environments (VEs) can thus be a very attractive approach in education process by reconstructing, as much as possible, the real environment and context of traditional education.

For example, Chittaro showed in [10] the different components to use in a VE in order to reach such effectiveness:
- Using three dimensional graphics;
- Interacting with another human being;
- Involving more senses in the acquisition process;
- Using collaborative VEs;
- Using virtual teachers, or animated pedagogical agents.

Concerning the domains in which 3D VEs can be used for education purpose one can mention: teaching and learning optics, anatomy, manufacturing and maintenance, robotics, etc. [11] Relying on the previous arguments and references, we decided to adopt the web3D technology in the realization of the EMULACTION project to preserve the richness of the subject.

3.2 Software architecture of EMULACTION

Most interactive game-like 3D web applications use commercial-ware means such as Adobe Flash[1] or Shockwave[2] or open-source but cumbersome Java applets which communicate through dully configurable sockets to display content.

One of the main features of EMULACTION is that it uses open-source technology to create a viable distributed learning environment using communication between JavaScript (with AJAX) and the X3D/VRML world. Like any

---

[1] http://en.wikipedia.org/wiki/Flash_animation
[2] http://en.wikipedia.org/wiki/SWF

complex web application, it uses a PHP and MySQL backbone for user and interface management, JQuery[3] for interface enhancement, and FluxPlayer[4] for X3D rendering.

Having a means of communication with the 3D world, one now needs to add dynamism to the equation. A virtual world is made of objects that have properties; position, rotation, size, colour, logical variables, input, output and even URL addresses must be stored to properly generate an environment for practical activities. Distribution means multi-user, thus the world must contain avatars to impersonate the users who are present in it. Decorative aspects must also be taken into account to add a realistic touch to the virtual experience. Just storing the objects in the database is not enough though; dynamism means movement and movement means spatial and logical coordinates.

To deal with these musts, EMULACTION benefits from a detailed database enabling the storage of information from the level of classrooms to the one of properties. But this information has to be used to dynamically generate the world, so AJAX was used to retrieve XML documents generated with PHP that contain the current state of the room. To simulate a direct connection with the server, a periodic request is made to update the world.
User interaction is handled through JavaScript object listeners that tap into the X3D embedded file and changes are sent to the server. Avatars are also treated as objects, but the personal avatar is bound to the movements of the user; in this way each user can be aware of other users' location. User's interface is nonetheless important; window space must be used to its fullest to embed all functionalities of the application without the need to scroll down. JQuery is a JavaScript framework that makes working with draggable windows and collapsing tabs easy, and makes the choice for EMULACTION's user interface.

A window-oriented interface is used to exhibit the room a user is present in, along with additional tools, such as text/voice/video chat allowing communication between online users, as well as other tools such text/code editor, workspace file manager, etc. for a smooth functionality.
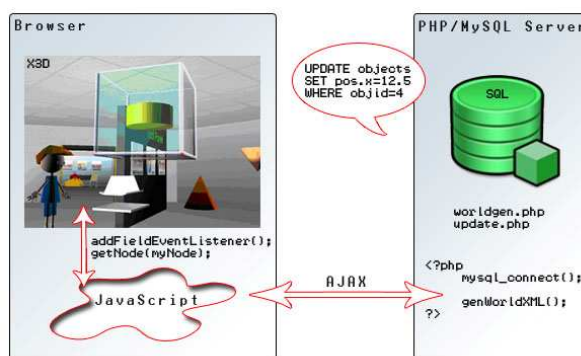

FIGURE 4
ARCHITECTURE AND WORKING PRINCIPLE DIAGRAM OF EMULACTION

Figure 4 describes the communication that takes place between the components of the application. A robust object-oriented JavaScript engine solves client-side management issues, while an AJAX module is used to query for the world's current state and to update the server with information. The update rate can be set down to 100 milliseconds without crashing the browser and resembles a real-time connection, making it possible for users to visualize the actions of fellow classmates and to interact.

3.3. Plug-in concept

When developing an application, regardless of the field in which it will be used, one needs stable software architecture, code flexibility, but most importantly a means to extend the life of the application. Moreover, according to Wilson, an environment good for learning cannot be fully pre-packaged and defined [6]. This is the reason why we implemented a mechanism of plug-ins.

The concept of plug-ins is a widely-known and efficient solution for enabling an application to be extended after its development has ended. A plug-in is a piece of code that can be developed by a third party and inserted into an application for usage. In the context of distributed virtual environments there is constant need for change: new objects to fill the ever-growing 3D world.

---

3 http://jquery.com
4 http://www.vivaty.com

Many successful web applications and software use the plug-in paradigm to enhance user's interactivity, security or performance (e.g.: Mozilla Firefox[5], Joomla[6], etc.).

To set grounds for plug-in support, a developer should separate the software logics from the visual content. The project EMULACTION makes use of a MySQL database to store the configurations of the virtual classrooms that are later used to create instances in which the users can practice. The main principle on which the web application was based is to provide a flexible framework for classroom creation; a plug-in installation form is available that enables the teacher to use new educational entities such as sonar scanners, electronic circuit boards, graph simulators, etc. As simple as it may sound, a single object may use quite a lot of files to provide its functionality, thus we decided to set a standard for zip-archived object packages.

An object package for EMULACTION consists of a main X3D/VRML file that may use other *.x3d/*.wrl files or textures inside the archive, and an XML file that instructs the installer module about the properties of that specific object: a property can be any attribute ranging from position to colour or Internet link. The real purpose of the properties is to enable the JavaScript engine to tap into the virtual world and dynamically generate the scene with every stored aspect of it.

The plug-in package was developed with the idea of making its installation as simple as possible in order to increase user's friendship; it consists of a GUI browsing option that allows the user to select the zip archive containing the object package, and an install button (Figure 5.1). Once installed, an object is accessible through the classroom generation module, in which the teacher can choose and place the content of a room (Figure 5.2).
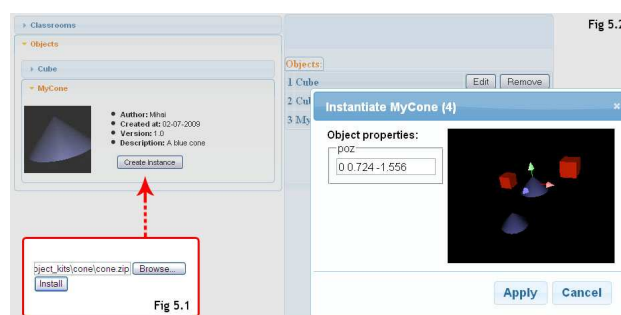

FIGURE 5
OBJECT INSTALLATION AND CLASSROOM CONFIGURATION INTERFACE

Through the concept of plug-ins we can develop the application without the need to create all possible object types (infinite possibilities) from the beginning. This way, third parties can create their own custom virtual gadgets to use inside this educational environment and effectively adapt the system to new educational contexts.

4. CASE STUDIES

4.1. Electronics

In the framework of electronics, students have to implement and to simulate circuits. In order to achieve these tasks we provide them with a virtual world that contains virtual components and virtual electronic equipment. Inspired from previous work [12], implementation and distribution of the virtual world are based on the same principles that are described in paragraph 3.2. A demonstration is available at the following address: https://web-brest.isen.fr/Vlab/

Students can use passive or active components. Some examples are shown hereafter (Figure 6 and Figure 7).

Students can choose a value for resistors or capacitors by selecting the right colours on the components according to colour codes. Concerning the other components, a menu has been implemented that enables students to choose a value.

---

[5] http://www.mozilla.com
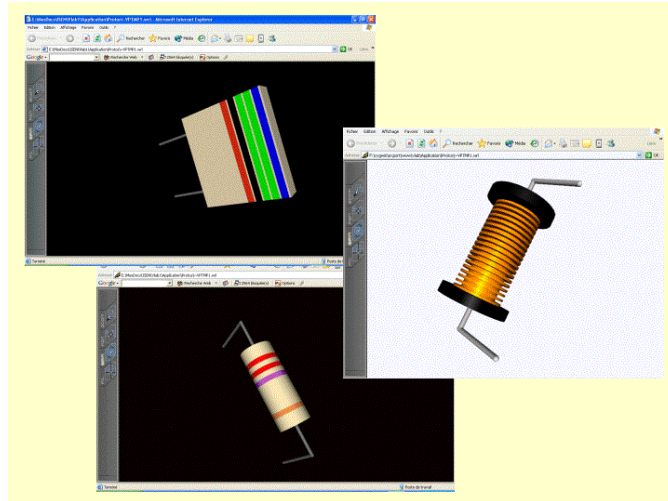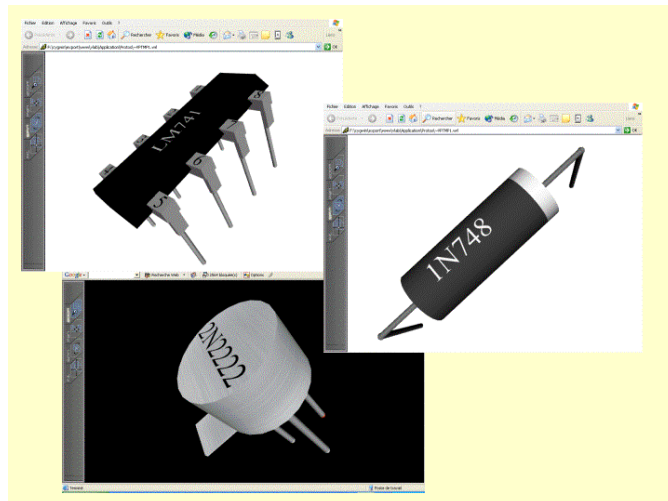[6] http://www.joomla.org

FIGURE 6
PASSIVE COMPONENTS

FIGURE 7
ACTIVE COMPONENTS

Components are inserted into the virtual world by clicking on the corresponding icon (Figure 8). Students can move (or rotate) components by means of virtual axis (Figure 9) that represent the directions of the movement.

FIGURE 8
COMPONENTS AND EQUIPMENTS CHOICE

After they have placed components on the virtual PCB (Printed Circuit Board), students can build their circuit by clicking on components' pins behind the virtual PCB (Figure 10).

International Conference on Engineering Education ICEE-2010   July 18–22, 2010, Gliwice, Poland.

7

FIGURE 9
MOVING COMPONENTS

FIGURE 10
DRAWING THE CIRCUIT

Two types of virtual electronic equipment (Figure 11) are available: generators and oscilloscopes. Generators 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. Oscilloscopes enable students to view circuits' outputs. That is to say: "simulation results". For each oscilloscope two channels are available. Students can adjust voltage and/or time scale.
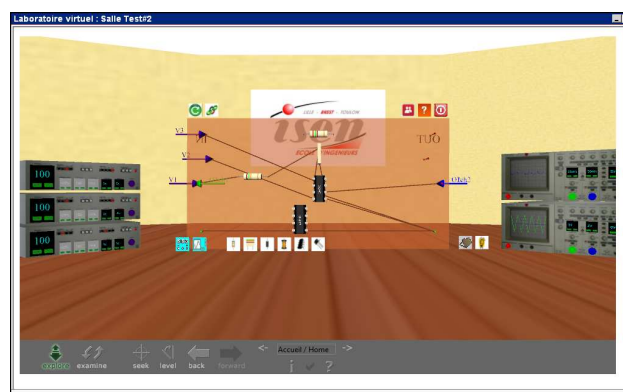

FIGURE 11
VIRTUAL ELECTRONICS EQUIPMENTS

In order to enable file sharing and to facilitate communication between students a file manager and a chat (Figure 12) have been implemented.

International Conference on Engineering Education ICEE-2010   July 18–22, 2010, Gliwice, Poland.

8

FIGURE 12
FILE MANAGER AND CHAT

To improve interaction between participants, an audio conference module is available in each room. To enter the conference, the user just has to click on the phone icon (Figure 13). This module has been experimented in the virtual electronics laboratory.

FIGURE 13
AUDIO CONFERENCE

There are examples of audio conference integration in X3D distributed world [13] but they are using H323 signalisation. Today more and more audio applications implement the SIP protocol. Our system is based on Asterisk [7] Server for signalisation (SIP) and audio flux transfer (RTP). Integration in the X3D world is made by means of a Java Applet which is hidden for users and starts automatically.
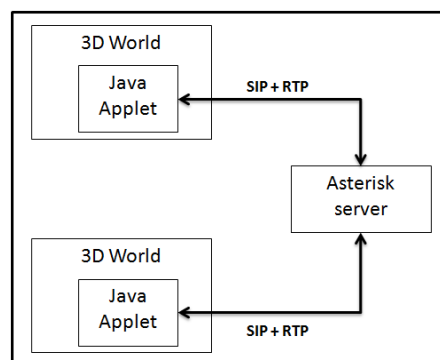

FIGURE 14
AUDIO CONFERENCE ARCHITECTURE

_____

[7] http://www.asterisk.org/

International Conference on Engineering Education ICEE-2010   July 18–22, 2010, Gliwice, Poland.

9

In order to guide students practical activities, pedagogical material had been designed. This material includes three parts:

1. **Practising Pulse Electronics** includes ten lessons that were complied by Engineer Pham Cong Huan[8]. Practicing lessons apply IC555 in creating Stable, Multivibratior and Monostable.
2. **Practising Digital Electronics** includes ten lessons that were complied by Engineer Dao Quang Khanh[8]. Practising lessons apply basic logic gates in circuits: Counter, Shift register, Demux, Mux, Decoder, Coder.
3. **Practising Analog Electronics** includes five lessons that were complied by Master Tran Thi Minh Chau[8]. Practicing lessons use amplifier and transistor.

4.2. Numerical Analysis

4.2.1. Introduction

The proposed activity consists in exploring, testing and implementing several methods used in numerical analysis. The studied case is the roots finding problem. The implemented algorithms are respectively: bisection, regula-falsi, fixed point, Newton-Raphson and secant. Other methods can be developed separately and added to the environment as plug-in modules.

4.2.2. Description of the activity

The user and/or group of users implied in the activity has the opportunity to participate in the activity in different ways.

a) Reviewing the theoretical background of the method (added as SCORM documents) as well as a graphical demonstration of its operation (Figure 15).
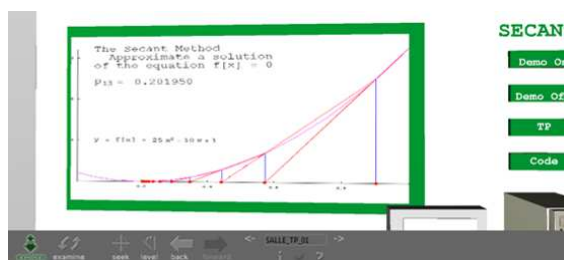

FIGURE 15
GRAPHICAL DEMO OF THE SECANT METHOD

b) Testing the different pre-implemented algorithms in order to compare their performance (convergence, accuracy, influence of their parameters, etc.) (Figure 16).
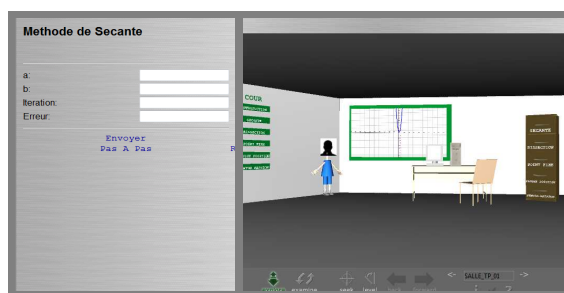

FIGURE 16
TESTING THE SECANT METHOD

c) Actively implementing the algorithms by adding the corresponding code to a proposed skeleton before executing it (Figure 17). During this phase users can work individually or in a collaborative way by sharing their results for the same or for different tested algorithms.

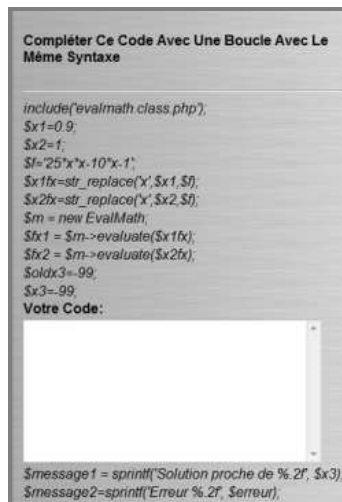
[8] Viettronics Technology College, Haiphong, Vietnam

FIGURE 17
ADDING CODE TO THE SKELETON

4.3. Digital Image processing

4.3.1. Introduction

The purpose is to make a group of students develop an image processing Tool by dividing the tasks between them. This will create motivation, stimulate the group work and promote cooperation and interaction among the students.

4.3.2. Method

The work is divided into tasks to be tackled as lab sessions. We opted for the JAVA development framework because it is open source, portable and reliable.

For each lab session, the objectives are defined. A sample of the source code is given to guide the students during the developing process. Based on the fact that the E-learning platform would allow the file share and transfer, the students will be able to exchange source codes and case study tests. Each student will tackle his/her task separately. Then the student submits the accomplished work to a responsible of the merge operation. The latter will compile all pieces of work together in order to build a full operational the image processing tool. To successfully complete, the lab sessions students should have some theoretical and technical background such as the notions of pixels and colours, and filters, combining images...

Source code required to complete the lab sessions are given to the group of students. Since the purpose is not user interface design, we prepared all control tools of events (buttons, keyboard events, menus, mouse events ...) and put them at the disposal of the learners, to spare the learner that sort of complexity not related to the scope of the academic content.

Thus, students should only focus on image processing and are not requested to be professional Java developer. To help them successfully complete all the lab sessions, they are guided through a step-by-step process. However they can custom the code as they want. An example of complete tool is available for download as JAR file (executable java program). This will give the students and idea on how should be their results.

4.3.3. Lab sessions

The work is split up into five lab sessions as follow:
1. Installing the environment and developing the tool frame with load (from file, web camera or print screen) and save images.
2. Basic operations : like inverting the image, adding, multiplying two images ...
3. Qualities processing by applying basic filters like Pyramid, Uniform and Gauss filters and getting the Histogram.
4. Characteristic extraction from the image (Prewitt, Sobel and Canny filters)
5. Application: face recognition using cross-correlation based on FFT transformation.

4.3.4. Technical environment

JAVA is an open source platform used in many fields in computer sciences. It uses its own library (javax.imageio) for image processing but could be extended with other packages like JAI (Java Advanced Imaging) that allows advanced operations on images. JMF (Java Media framework) is also used to manage the media flow and make it possible to capture images from devices linked to work stations.

4.3.5. Case study

To test our solution in the collaborative architecture, we asked three students (student #1, student #2 and student #3) to conduct one of the labs of image processing. For illustration, we choose the second one (Lab 2 : "Basic Operations").
The students discussed distributing the tasks by using messages, file sharing and emails. Suppose that the application window and its menu have been already prepared in the previous labs. Based on that, the tasks were decided as follows:

Student #1: Developing the code to calculate the negative of an image. The result is the following:
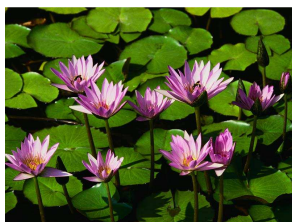
Input image: Output image:
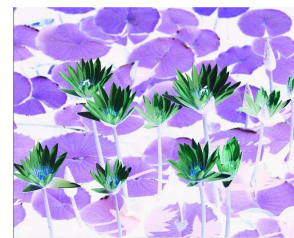

FIGURE 18
SOURCE IMAGE

FIGURE 19
NEGATIVE OF THE INPUT IMAGE

Student #2: Providing the JAVA classes and codes for the "Simple operation" window (shown hereafter) with the button functions such as opening and displaying files.

Student #3: The JAVA class for the three operations:
- Adding two images
- Subtracting two images
- Multiplying two images

For example, for the two following images (Image #1 and Image #2) as input we obtained the "resulting image" as output:
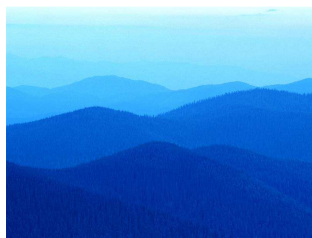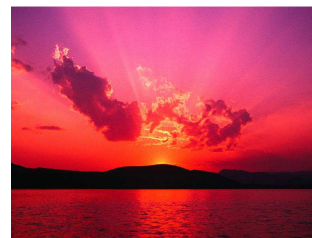

FIGURE 20
IMAGE #1

FIGURE 21
IMAGE #2

ADD OPERATION: SUBTRACTION OPERATION: MULTIPLICATION OPERATION:

FIGURE 22.
IMAGE RESULTING FROM ADDITION
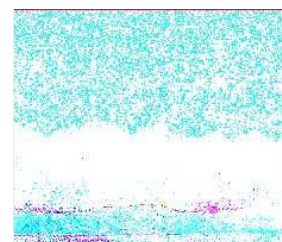

FIGURE 23
IMAGE RESULTING FROM SUBTRACTION

FIGURE 24
IMAGE RESULTING FROM MULTIPLICATION

After finishing all the tasks, the first student was asked to merge all source code into the existing application under the "Basic operation" menu.

5. CONCLUSIONS AND FUTURE WORK

In this paper we have presented a Digital Environment dedicated for pedagogical purposes. This environment is optimized for Mozilla Firefox 3.6 and compatible with the latest versions of Microsoft Internet Explorer, Google Chrome and Opera. It uses Flux Player as X3D viewer and relies solely on Javascript for object management.
The EMULACTION environment will be tested by the end of this year with students from six countries: Canada, France, Lebanon, Moldova, Romania and Vietnam, complementary to traditional practical activities.

The purpose is not to replace traditional practical activities but to enhance the students' ability to practice. This way, we hope to increase students' performance as much as possible during face-to-face activities, by preserving the richness and the complexity of the learning environment, and providing tools and support for them to "learn their way around" [4].

ACKNOWLEDGEMENTS

REFERENCES

[1] Kremer, R. (1994), *Concept Mapping: Informal to Formal*, ICCS'94, Proceedings of the International Conference on Conceptual Structures, University of Maryland, 1994

[2] Advanced Distributed Learning (2006). SCORM 2004 3rd Edition, Sharable Content Object Reference Model – Content Aggregation Model

[3] Cikic,S., Jeschke, S., Ludwig, N. and Sinha, U. (2007) *Virtual and remote laboratories in cooperative knowledge spaces*, In: IASTED International Conference on Computers and Advanced Technology in Education (CATE 2007), Beijing, China, October 8-10, 2007

[4] Wilson, B.G. (1995). *Metaphors for instruction: Why we talk about learning environments*. Educational Technology, 35(5), pp. 25-30

[5] Hampel, T. and Keil-Slawik, R. (2001). *sTeam: Structuring information in a team – distributed knowledge management in cooperative learning environments*. *J. Educ. Resour. Comput.*, 1(2es):3

[6] Greenberg, S. and Roseman, M. (2003). *Using a room metaphor to ease transitions in groupware*. In Ackerman, M., Pipek, V., and Wulf, V., editors, *Sharing Expertise: Beyond Knowledge Management*, pp. 203–256, Cambridge, MA, MIT Press

[7] Popovici, D.M., Septseault, C., Querrec, R. (2006). *Motivate Them to Communicate*, In: Proceedings of CW2006, Geneva, IEEE Computer Society, pp.198-205

[8] Bos-Ciussi. M., Augier. M, and Rosner, G. (2008), *Learning Communities Are Not Mushrooms - or - How to Cultivate Learning Communities* in Higher Education In: Communities of Practice: Creating Learning Environments for Educators, C. Kimble, P. Hildreth and I. Bourdon (Eds), Information Age Publishing. Vol 2, Ch 14, pp. 287-308

[9] Perkins, D. N. (1995). *Outsmarting IQ: The emerging science of learnable intelligence*. New York: The Free Press

[10] Chittaro, L & Ranon, R. (2007). *Web3D technologies in learning, education and training: motivations, issues, opportunities.* Computers & Education 49(1), pp. 3-18

[11] Proceedings of the First International Workshop on Web3D Technologies in Learning, Education and Training, University of Udine, Italy, October 2004

[12] J-P Gerval, Y. Le Ru, *VELab: A Virtual Lab for Electronics Virtual Experiments*, Advanced Technology for Learning, Volume 3 - Issue 2, ACTA Press, 2006

[13] Ch. Bouras, Ch. Tegos, V. Triglianos, Th. Tsiatsos, *X3D Multi-user Virtual Environment Platform for Collaborative Spatial Design*, 27th International Conference on Distributed Computing Systems Workshops (ICDCSW'07) Toronto, Canada, June 25-29, 2007