DISTRIBUTED MULTIMEDIA SYSTEMS FOR COMPUTER BASED LEARNING IN ANALOG AND DIGITAL ELECTRONICS

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ABSTRACT.- The paper presents our work in the field of Computer Based Learning (CBL) for analog and digital electronics. The approach is centered on the construction of learning environments, based on a wide and graduated collection of learning tools, from simple concept animation, through educationally-oriented general purpose tools, to sophisticated professional circuit simulations. Tools are bundled together by a hypertext. The most recent development is the evolution of the existing learning material into a distributed system that integrates CBL material with network services. The communication facilities implemented through the network reintroduce within the domain of CBL the interactivity features that have characterized, since the very beginning, the relations between teachers and learners.

1.- INTRODUCTION

Our group has been engaged since a few years ago in the development of Computer Based Learning (CBL) material to be employed as a support for the teaching of fundamental issues of analog and digital electronics for the curricula of Electronic and Computer Science Engineering. The project has been supported in the past by the European program COMETT (project WORKBENCH) and now by the Telematics Application programme ARIADNE [1]. The synthesis presented here deals with the basic issue of the use of computers for education in electronics from an almost historical point of view, showing how technological advances of software tools, combined with the experience gained by developing courseware, have guided the evolution of the teaching approach.

The unifying aspect of the work is the constant effort to develop an environment where the basic pedagogical activities that constitute what is called "teaching" of electronics are enhanced by the use of computers. Such activities can be identified as the following ones:

1. presentation of theory and concepts;
2. interactive explanation of the theory;
3. verification of learning;
4. guided practice through sample problems;
5. open practice of circuit and system design.

In the following, the CBL material developed so far is divided into three successive generations, as shown in the Table I, and each one is examined in terms of how and how successfully the pedagogical activities mentioned above are implemented. the first two generations are concerned only with stand-alone CBL material, to be used independently by the learner, the third one, still under development, explores the pedagogical potential

Generation	Course	Subject	Delivery of contents (theory)	Interactive explanation of theory	Verification of learning	Exercises	Design practice	Interaction with teacher
1st	WB.GUI (English)	Analog Electronics	Hypertext (OWL Guide)	SPICE-based simulations	——	——	SPICE	——
	ESD.GUI (Italian)	Digital Electronics	Hypertext (OWL Guide)	——	——	——	——	——
2nd	WB.TBK (Italian)	Analog Electronics	Hypertext and animations (Asymetrix ToolBook)	Local simulations embedded in hypertext	——	——	SPICE	——
	ESD.TBK (Italian)	Digital Electronics	Hypertext and animations (Asymetrix ToolBook)	Local simulations embedded in hypertext	Multiple Choice Questionnairre (MCQ)	Interactive exercises and simulations (ToolBook)	Z80, ASM, and Digital simulators	——
3rd	WB.NET (Italian)	Analog Electronics	HTML and ToolBook files (TBK)	Local simulations embedded in hypertext	——	——	SPICE	Teacher-learner Learner-learner on Network
	ESD.NET (Italian)	Digital Electronics	HTML and ToolBook files (TBK)	Local simulations embedded in hypertext	MCQ	Interactive exercises (HTML+TBK) Cooperative work	Z80, ASM, and Digital simulators	Teacher-learner Learner-learner on Network

Table 1.- Synoptic table of the courseware for analog and digital electronics developed at D.I.B.E. - University of Genoa.

offered by network communications, using a computer network to deliver pedagogical material and exchange information between tutors and learners.

2.- FIRST GENERATION: THE HYPERTEXT

The first CBL system to come to life has been the WORKBENCH station, a learning system for analog electronics conceived to guide the student through the three classical phases of delivery of theoretical material, practicing with exercises and simulators and conduction of laboratory experiments [2]. The first generation was based on OWL Guide, one of the first hypertext generators available under Windows and produced two courses, code-named WB.GUI for analog electronics and ESD.GUI for digital electronics. In this approach, hypertext was central to the courseware structure, as the main vehicle to convoy information to the learner. Its purpose was to provide the theoretical frame of the lesson, and the courseware's content was equivalent to the one of a traditional printed textbook.

A strong point in WB.GUI was the integration of a circuit simulator, used for a double purpose: to demonstrate the concepts and sample circuits introduced in the theory, and to allow the learner to design and test autonomously an unlimited number of networks of his own conception, verifying by software simulation their correctness.

The introduction of a general purpose simulator in a course of electronics had been quite extensively reported in the literature, but its integration with the hypertext containing theoretical contents represented a step forward. WB.GUI integrates the professional package SPICE, a "classic" analog circuit simulator written in the mid 70's at the University of California at Berkeley, extensively used in both academic and industrial environments and well documented. Such diffusion has stimulated the extension of the use of the program to direct educational purposes, in order to provide the benefits of circuit simulation to undergraduate curricula. In our system, the original SPICE program has been integrated with custom-developed tools, such as a circuit editor and waveform display, designed to make its use simple and practical in an educational environment [3].

The part of WB.GUI dedicated to laboratory experiments used a custom-made hardware interface to allow the use of the Personal Computer as a measuring instrument. The role of courseware was to guide the learner to set up a circuit and to test it in the real world. More details can be found in [4].

WB.GUI has been extensively tested, being used as a support for the course of Applied Electronics. The experience gained in the process has shown as strong point the availability of professional simulation features (SPICE), that were continuously used by the learners, while the hypertext (written in English) containing the theoretical material got much less attention. Furthermore, the idea of demonstrating even simple concept through Spice simulation, very good in principle, proved to be, in many instances, quite cumbersome weak ones (the hypertext delivery).

3.- SECOND GENERATION: THE LEARNING TOOLS

The evaluation of the first generation courseware has prompted and guided the development of a somewhat different approach, the basic aim being the enhancement of the first of the five pedagogical actions quoted in the introduction, delivery of theoretical material. The solution has been found in the creation of a layer of "learning tools" to foster an intuitive understanding of concepts instead of relying only on textual explanations, or to demonstrate them after a conventional explanation [5].

With the term "animation" we mean a large class of techniques that goes well beyond its literal meaning of moving images. In many scientific and technical fields, descriptions of processes that can be difficult to explain by text alone become, in fact, very simple and intuitive if the text-based description is substituted, or integrated, with direct animation. A typical example of animation is the dynamic representation of the data flow in a microcomputer fetching and executing an instruction. Animation has also the advantage of capturing the learners' attention.

The learning tool most widely used in the course is what we call "local simulation". They could be described as something in between the animation quoted before and a classical software simulation of a system or process. While animation gives a representation of a process every time in the same way, local simulation allow the user to interact with the learning environment. by setting the values of some of the process variables. An example of such methodology may be represented by the simulation of the execution of a microcomputer instruction, where the student is able to modify the input data and observe results that depend on the data. Animation and simulations have been developed using the features offered by hypertext authoring tool (OpenScript is the programming language of ToolBook) and, as a consequence, they are embedded in the hypertext itself.

With the massive use of learning tools, the original approach of centering the learning process on the hypertext, has therefore been reversed. Instead of a hypertext-based course, integrated by simulators, and laboratory practice, we came up with a sort of collection of tools for the student to use, where the role of the hypertext is to provide the necessary explanations and the theoretical framework upon which the student activity can be finalized into effective learning.

The new version of the analog electronics courseware (WB.TBK), while confirming the use of SPICE simulations, replaces the original hypertext with a new structure where text is reduced to a minimum and understanding is achieved through the use of animations, local simulations and other pedagogical tools that introduce the fundamental issues of the course. To achieve this goal, the new courseware takes advantage of the better features provided by Asymetrix ToolBook. Learning is therefore initiated by a sort of exploration of components and circuits that, in force of their OpenScript programming, respond appropriately to stimulation, that is applied in a graphical, user-friendly way.

With the same approach has been produced ESD.TBK, a course on the foundations of Digital Electronic Systems, from Boolean algebra to sequential networks, state machines and microprocessors, enriched by a large amount of ToolBook-made learning tools. Digital electronics lends itself very well to this kind of presentation: in ESD.TBK local simulation has been used to a much larger extent than in WB.TBK. For example, we have produced models of logical components that, in force of their OpenScript programming, respond to mouse input in the same way as real components respond to signals. Data sheets made in this way are therefore "alive".

For the verification phase of the learning process, short, rapid multiple-choice and true-false quizzes (MCQ) have been built to recall all the topics of the course. In these tests wrong answers bring up text fields that explain why the answer was incorrect, and a score is generally computed and given to the student.

A large amount of sample problems, including all past written examinations of the last few years, are part of the courseware and are among the most frequently consulted material. A student is generally asked to develop a digital system based on a finite state machine, to write a software algorithm as program in Z80 Assembly and to analyze a sequential network in the time domain. The solutions are explained to the learner in two different

ways, as a simulation of the behavior of the digital system or software algorithm and as a step-by-step guide to the development of the same [6].
A quite difficult problem to solve for the courseware on digital electronics has been the integration of a general purpose network simulator. While for analog electronics SPICE simulation is widely adopted in the university and professional environments, the situation is different when dealing with digital networks. First of all, professional tools are designed to satisfy the practicing engineer needs and, generally speaking, do not have a pedagogical orientation. They are usually closed systems and do not lend themselves to be modified with the addition, for example, of an on-line help. Another not negligible problem is represented by their cost, often non compatible with their use in schools.
In conclusion, given the fact that general purpose tools are central to the creation of CBL material for science and technology, and given also the obstacles that discourage the use of ready-made professional tools, we decided to develop our own digital simulators.
The three tools, general purpose simulators of digital networks (DIGSIM), state machines (FSMSIM) and microprocessor emulator (EMUZ80), are the more complex components of the courseware. They are custom-built applications with approximately the same characteristics of professional CAD tools for electronics, except that their design has been carried out with a strong pedagogical orientations. As an example, special care has been put into error management, providing short, but thorough, explanations of the problem. Their construction has required programming instruments beyond the hypertext's OpenScript language, which is too limited for this purpose and, as a consequence, they are not integrated within the lesson but they appear as windows. More details on the simulators can be found in [7].

4.- THIRD GENERATION: THE NETWORK

Computer Networking Technologies (CNT) are nowadays well established and are proving themselves to be a very important prerequisite for creating more efficient learning environments. They provide the possibility of maintaining a repository of learning material that can be easily updated, demonstrated, downloaded or executed on-line. More than that, a network-based learning system has the possibility to reintroduce within the domain of CBL the interactivity features that have characterized, since the very beginning, the relations between teachers and learners.
CBL and CNT can cooperate in providing a flexible and cost-effective approach to the problems of education in electronics. While the former provide pedagogical structure and contents, the latter adds the interactivity that enhances the learning process. In our case, while the contents and methodologies are the ones just explained, course delivery, teacher-learners interaction and cooperative work take place in Internet, using properly designed tools. In the following, we describe the experimental courses on the network that will take place in the academic year 96-97 [1].
The learner accesses the course through a personal computer, either from a LAN (in our case, a PC laboratory) or from home with a modem. The first time, he is asked to identify himself and to register. After registration, he has at his disposal several resources. First of all, access to the learning material, with the choice, for the expositive documents (texts and hypertexts) of consulting them on-line or, instead, downloading them from the system server. Downloading is mandatory for executable files, such as the circuit and state machine simulators and microprocessor emulator, that can only be run locally. Downloading generally minimizes connection times and costs. Information of different

nature, such as rules and dates of verification workshops and examination sessions, can also be found on the server, together with lists of Frequently Asked Questions (FAQ) divided by subject.
Every student is assigned a mailbox and has the possibility of exchanging messages with the teacher and other students. Another important feature to encourage active learning is the creation of a space for cooperative work, where the teacher can propose problems to solve. The interested students deposit their solutions or questions in the same public space; the teacher periodically overviews the work and guides it to conclusion. The course, that by its own nature is fully asynchronous, will be paced with approximately the same timing as a traditional class. A few times a week the teacher will propose items to study and exercises to solve from the courseware repository, and the cooperative work will be used accordingly. The verification phase of the learning process is very important both for the student (that can test his own preparation) and for the teacher (that can take it into account to fine tune its pedagogical action). In our system we plan two kinds of verification: verification workshops, carried out periodically with the help of Multiple-Choices Questionnaires (MCQ) and final examinations, characterized by more strict procedures for student identification and adherence to rules. More information on the network-based course can be found in [8].

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