Multimedia and Virtual Reality in Architecture and in Engineering Education

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Abstract: The evolution of multimedia and of Virtual Reality (VR) technologies can open new educational opportunities in architecture and in engineering education. This paper describes some examples in these two educational fields.

Key-Words: Multimedia, Virtual Reality, Hypermedia, Virtual Instrumentation, Architecture, Engineering.

1 Introduction

Multimedia is the use of several different media (e.g. text, audio, graphics, animation, video, and interactivity) to convey information. Multimedia also refers to the use of computer technology to create, store, and experience multimedia content. The use of computers to present text, graphics, video, animation, and sound in an integrated way can offer new opportunities in educational environment. With increases in performance and decreases in price of the hardware, multimedia is now commonplace.

Virtual Reality (VR) is an environment that is simulated by a computer. The origin of the term virtual reality is uncertain though. It has been credited to *The Judas Mandala*, a 1982 novel by Damien Broderick where the context of use is somewhat different from that defined now.

As a medium, VR has three defining characteristics [1]. It is:

- Interactive, users can interact with models;
- Spatial, models are represented in three spatial dimensions; and
- Real-time, feedback from actions is given without noticeable pause.

VR can be classified according to its methods of display; we have:

- immersive VR which involves a high degree of interactivity and high cost peripheral devices, for example the head mounted displays; and
- non-immersive VR is often called desktop VR and it is in the form of a windows into a virtual world displayed on a computer's monitor [2].

A virtual reality system has the three primary requirements: immersion, interaction and visual realism [3].

This paper, that describes two applications in the educational fields of multimedia and VR technologies, is organized as follow: section 2 shows the use these technologies in architecture, section 3 presents some application fields in engineering education, section 4 presents our conclusions and the future trends. The section 5 is dedicated to the references.

2 Multimedia and Virtual Reality In Architecture Education

Multimedia are revolutionizing the ways in which we share information. In particular, it is affecting methods of teaching and learning [4, 5]. We analysed the teaching impact of multimedia technologies in a faculty of architecture. The investigations is following the question: "Is it possible to organize some academic courses of Mathematics for specific disciplines using multimedia solutions and virtual objects integrated in the teaching path?"

To answer it, two courses of mathematics specifically conceived for the Faculty of Architecture at University of Lugano (Mendrisio, Switzerland) have been organized starting from 2000 [6]. First course, named "Mathematical thought", was inserted in the first year of the studies until 2004 (5 credits ECTS, European Credit Transfer and Accumulation System). It introduced basic facets of mathematical thought connected to the arts and to the architecture (e.g., the symmetry, the golden ratio, the surfaces, the fractal geometry and the complexity).

The second course, named "New media for the architecture" (third year, 5 credits ECTS), is actually in the curriculum of the faculty. The course intends to propose how new media and the graphics solutions can create new architectural shapes, for example hypersurfaces, and new kind of architecture (for example, cyberarchitecture transarchitecture, and hyperarchitecture).

In these courses, we integrated the traditional lectures using multimedia as a teaching strategy, because 60% of students today are visual learners [7, 8]. This category of learners may benefit most from multimedia presentations, which combine words with pictures and audio can help to redefine the teaching methods [4, 7, 8]. The lectures are organized using:

- hypermedia presentation;
- animations in Java language;
- scientific documentaries; and
- data streaming, dedicated of information and communication technologies, available online (http://www.nova-multimedia.it).

Inside this educational environment, virtual reality objects have been created to explain 3D surfaces and the structure of the buildings [6]. Recent studies have recognized that virtual reality offers benefits that can support the education and the design project, in particular in the faculties of architecture [1, 10, 11, 12, 13, 14, 15, 16].

VR technology has been used firstly to help architecture students to visualise in three dimensions, since this is arguably the most difficult part of understanding architecture. In the same faculty, VR is also integrated in multimedia presentation to describe “virtual walkthroughs” in the buildings, as shown in figure 1. It reproduces Ville Savoye (1929-1931) a Le Corbusier’s project.

Fig.1 - VR in architecture: an example of virtual building (Ville Savoye)

This educational approach is important, because the design is affected by the medium used [1]. Henderson (1999) notes that: “Young designers trained on graphics software are developing a new visual culture tied to computer-graphics practise, that will influence the way they see and will be different from the visual culture of the paper world” [17, p. 57]. Architects who have grown up with digital media and virtual reality will be expert users of interactive, spatial, real-time environments [1, 18]. They will use fractal algorithms, written in Virtual Reality Modelling Language (VRML), to create virtual worlds, where the realism plays a central role. These designers will solve problems using representations that do not emulate paper-based media.

Virtual model of Ville Savoye, shown in figure 1, has been created using VRML, which is a language that specifies the parameters to create virtual worlds networked together via the Internet and accessed via the World Wide Web hyperlinks. It permits to realize VR’s low cost applications. VRML was conceived in the spring of 1994 and it has been presented to the first annual WWW conference in Geneva, Switzerland. VRML offers a number of attractive features:

- it has cross-platform compatibility;
- much of the software for creating VRML content can be downloaded for free; and
- as VRML sits upon existing World Wide Web tools.

VRML defines a set of objects and functions for modeling simple 3D graphics. These are known as nodes, which are arranged in hierarchies called scene graphs. There is a top-down arrangement in which nodes that are described earlier in a scene affect later ones, but this can be limited by the use of separator nodes. The aim of VRML is to bring to the Internet the advantages of 3D spaces, known in VRML as worlds whether they compromise environments or single objects. These are built to be shared between widely distributed users. A VRML file is an ASCII file with the suffix .WRL (Web Rule Language), which is interpreted by the browser, for example Cosmoplayer^{TM} or Cortona^{TM}, and converted into a 3D display of the described world. Applications in architecture also include a more complete analysis of the design due to viewing it from any angle; and the communication of designs to clients using "3D walkthroughs". Walkthroughs might include voice commands, sounds, and touch. To realize this "Virtual Urban Design" is required to realistically simulate data including traffic flow of people and transport. Databases are set up which include this constantly changing information.

Other application of VR in the urban design involve the use of "virtual models" in the following ways:

- To model proposed urban "guidelines" for newly developed areas. For example, different housing proposals could be compared for a vacant city block; and

- To model existing urban precincts which require constant reappraisal. For example, "virtual urban designers" could walk through urban spaces and observe how they might be better used. City commercial spaces may be replaced by urban dwellings.

Fully immersive virtual reality programs are an important way to experience digital architectural models, but they don't always provide the best view, especially where action is involved, because it is necessary a complex process of rendering which involves computer graphics techniques of radiosity and ray tracing. These applications emphasize that one problem at the moment is the cost to realise immersive virtual reality environments.

The price for educational application of VR may drop if the market grows, but in terms of products for education we have to pay much for modest quality hardware and software. Other problem is connected to the simulation of some effects that are familiar to the human body. For example, haptic feedback is not like the real tactile sensation.

3 Multimedia and Virtual Reality In Engineering Education

Multimedia and virtual reality technologies can help the educational path in the faculties of engineering. The Department of Electronic, Politecnico of Torino (Italy), introduced hypermedia modules to expose students to a comprehensive range of electronic instruments and basic measurements techniques; and to allow them to give practice on the particular instrument whose front panel is simulated on the monitor and the behaviour is emulated by computer. It involved in activating traditional degree and diploma courses in several educational structures, throughout the Piedmont region. At that time requirements stemming from a large demand for education on experimental subjects and laboratory training had to be met with limited human and financial resources.

Education in fields such as electronic measurement requires students to gain a reasonable skill in using various kinds of instrumentation. The cost of basic level instruments is often low, but large classrooms means large workbench availability and a massive and qualified assistance that is not easily found. Basic instrumentation teaching is required for first level courses that are followed by a large number of students [19, 20].

The most of the time which the students spent in the laboratories, especially for first level courses, was devoted to learning the operating functions and the use of the same basic instruments. It was therefore decided to invest time and resources to develop an alternative solution to the laboratory replication by using the new technologies offered by computer based multimedia courseware. The goal was to allow the students to carry out a pre-training activity outside the laboratory and possibly at home; each student could thus individually adequate the learning rate to his own capabilities. After this pre-training phase, students who enter the laboratory require reduced assistance and less time to complete the training activity.

Umberto Pisani (Politecnico of Torino, Italy) reorganized his traditional educational approach, based on lectures and successive laboratory practice, using multimedia tools which combine two different learning phases: a theoretical phase, and a practice phase in a single tutorial stage self-managed by the student [19].

In these activities the author was involved as expert witness for the didactic paths and the correct use of the multimedia codes in educational process. These didactic modules have the following purposes:

- to expose students to a comprehensive range of electronic instruments and basic measurements techniques;
- to allow students to give practice on the particular instrument whose front panel is simulated on the monitor and the behaviour is emulated by computer.

This multimedia course was structured on a set of lessons (modules) each containing a particular topic or instrument in form of a self – contained multimedia presentation. The multimedia modules developed are: the fundamentals of the analog oscilloscope, the analog and digital voltmeters, and the IEEE488 standard interface for programmable instrumentation.

Differently from the other multimedia applications this case is oriented to defined objectives of knowledge and it is based on a student model with a defined knowledge background, so it was decided to guide the students through a path, based on a structured didactic methodology, to reach the proposed educational goal (we have used the Bloom’s taxonomy). Each module, developed using Multimedia Toolbook™ (with the aid of several thesis student), is divided into subjects (pages) at the same hierarchical level; each level contains a subset of other pages, placed at a lower levels. Hyperlinks among pages have been studied to give continuity to learning trail.

In these modules different media were involved, for example some animation techniques (which are an efficient learning tool, when the teaching of a subjects would be difficult by a written description alone), the digital television camera images (to zoom an instrument inside), some audio supports to emphasize some topic in a lesson (e.g., to explain an electronic circuit). Virtual instruments were implemented in the multimedia packages (developed in the VisualBasic™ environment with the exception of a minor part written in Microsoft C++™ and Java™ language), in order to allow simple simulations of the real instruments during the self-training phase. For example, when learning the oscilloscope, the student, after setting a particular input signal, can evaluate the effects of different instrument configurations on the simulated screen (figure 2).

The flexibility of the course organization helped students to adapt the learning rate to their time availability and their cultural background. They can study the theory and then self-verify their knowledge level by solving practical exercises and answering a series of questions. The student only need an inexpensive personal computer with a multimedia extension, that is available in centralized structures of the university or possibly at home.

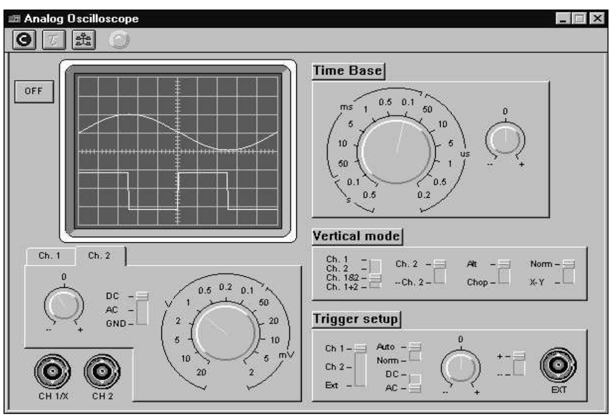

Fig.2 - Virtual instrumentation: the front panel of an oscilloscope

The applications of VR technologies in engineering can involve the education, the training and the design. VR technologies can also help the applications designed to provide for the development and practice of work-related skills. Antonietti et al. (1999; 2001) proposed a prototypal system for machine tools teaching in a Virtual Reality environment integrated with hypermedia [21, 22]. The goal is to lead students not only to understand the structure and functioning of the lathe, but also to use such a machine. To reach this, the prototype tries to foster conceptual changes in students' mental models and to increase students' control over the learning process. A series of experimental tests have been carried out to assess the educational validity of the instructional tool which has been devised. The aim of the first phase of the project was to assess whether students could use easily the virtual lathe and to verify what they learn about such a machine. The purpose of the second phase was to focus on some critical aspects of the learning process activated by using the virtual lathe in order to realise which are the instructional procedures which give the best learning outcomes.

Every year hundreds of students are injured in laboratory accidents, in spite of all safety precautions. One reason for this is that people tend to become forgetful and complacent, and stop observing safe laboratory procedures. Those who have experienced laboratory accidents, however, will remember those experiences much longer than any set of written rules.

Virtual reality can help to train the students to avoid the laboratory accidents. For example, at the Department of Chemical Engineering at the University of Michigan has been founded the VRiChEL laboratory to explore and develop the use of virtual reality in chemical engineering (http://www.vrupl.evl.uic.edu/vrichel/). The goal of the VRiChEL is to realize a set of VR based accident simulations, to allow users to experience first-hand the consequences of not following safe laboratory procedures.

VR's technologies are being used in various domains like of mechanical engineering, for example in the vehicle design, for example in the visualisation of vehicle architecture during the upstream phase. This is possible because the development of Computer Aided Design (CAD) and the geometric based design have reached a high level of maturity and affordability. CAD systems permit to the designer to evaluate the geometry of his virtual design. At this step of the design process, modifications are still quite cheap, compared with changes to a physical prototype or, even worse, the final product. Many companies use this "virtual" approach to improve the effectiveness and efficiency of the design process. This can be a very much time-consuming and expensive process [23].

4 Conclusions and Future Trends

Important deductive considerations are proposed from these educational approaches, they include that:

1) multimedia assists the teaching process (in fact, different communication codes in a lecture make more incisive the explanation);
2) the lectures are now more interactive (for example, in the laboratory activities the students can manipulate some virtual objects or they can navigate in hypermedia);
3) hypertext facilitates human learning, in agreement with other researchers [24], so long as the design of

the hypertext includes particular stratagems. For example, to design a "user friendly" graphics interface, and to define a map to avoid the Conklin's "lost in hyperspace" problem [25] or to study a hierarchical representation of information; and

4) hypertext supports the connection of ideas. In fact, the use of documents that are linked through hypertext allows the learners to jump from one learning context to another.

Virtual reality will have potential future applications in architecture and engineering which include:

- Marketing tool (for example, interactive adaptive displays, to demonstrate the use of different finishes on a building);
- Communication tool, cross distance and language barriers (for example, between the architect and client, and to educate architects and engineers);
- Evaluation modelling tool (for example, to study effects of lighting - natural and artificial, to evaluate acoustics phenomena, to simulate the properties' of the material); and
- Modelling/Design tool (for example, to analyse spaces by actually "getting inside them", to Incorporate rational data during schematic design stages, then look at different design solutions, to design "virtual architecture" and "virtual prototype").

Some of the possible benefits of VR on the design process and practice of architecture and engineering could be:

- the ability to test ideas in "real time" in a "three-dimensional" space during the design process;
- communication of ideas, and the power to convince authorities;
- the elimination of much of the guesswork in design;
- braver and better designs; and
- the integration of the design process.

In order to effectively apply VR as an educational tool in architecture, in engineering and other technical areas, a number of simulation difficulties have to be identified and solved, for example: to maintain high frame rates on PCs and the low resolution of inexpensive viewing devices.

One of the main aims of VR is to create virtual worlds and virtual environments in which humans can interact together. The problem of the interaction with other users and with virtual objects will raise in the next future. The realism presumably will play a major role in the programs' success and likely will prove positive in future endeavors. How to create the virtual worlds? Some virtual worlds will be oriented certainly to the educational field and other for training, works or fun. Architects will potentially help to make the virtual world a pleasant and stimulating place to work and live in, with a good quality of life. This will require people who understand the psychological effects of the spaces, generated by the computer, on people inside them, and the architects have to prepare themselves to this new work opportunity. Architects as designers of Virtual Worlds will be required to make these environments interesting, rich, and engaging places. Therefore, it is important to prepare a correct training on the use of VR in the faculties of architecture [1, 16].

Some architectural theorists are looking at VR as such an inhabitable alternative reality. Whyte (2002) affirms: "they describe objects in interactive, spatial, real-time media as though they existed in a new form of space, rather than in spatial representations and look at Novak (1996) terms the vitality of architecture after territory" [1, p. 46].

VR is also connected to the cyberspace. Novak argues that: "Cyberspace as a whole, and networked virtual environments in particular, allow us to not only theorize about potential architectures informed by the best of current thought, but to actually construct such spaces for human inhabitation in a completely new kind of public realm" [26]. For the architectural education, virtual reality will become the place to go to do things that you could not normally do in architect-designed buildings. Spaces created using Fractal and non-Euclidean geometry will exist and they could be modified using algorithms and computer programs [18, 27]. A crucial issue for integrating VR into architecture and engineering curricula is safety: some users, after the navigation in virtual world using the typical VR's devices, had ocular problems (e.g., blurred vision, eyestrain, and fatigue), disorientation and nausea. The next generation of VR tools will be studied to avoid these effects.

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