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Designing Virtual Environments in an Educational Context

Abstract: Virtual environments in which users can navigate freely through spatial representations, pick up and examine objects, and "converse" with virtual characters, can play a role in transferring information and knowledge for both training and education. This paper discusses design issues encountered when creating such an environment for grade-five primary school students.

Résumé : Les environnements numériques dans lesquels les individus peuvent naviguer librement à travers des représentations spatiales, obtenir et examiner des objets, et « faire la conversation » avec des personnages virtuels, peuvent jouer un rôle dans le transfert de l'information et des connaissances, aussi bien au niveau de la formation que de l'enseignement. Cet article présente les problèmes de conception rencontrés lors de la création de tels environnements pour des élèves de cinquième année de l'école primaire.

1. Introduction

Advances in technology and software engineering in the last decade have resulted in the development of engaging games, in which the user is immersed in a virtual environment. A study of some 2000 children between the ages of 8 and 18 reported that 83% have at least one video game player in their home (Roberts, Foeher & Rideout, 2005). While these games are marketed as entertainment, they can also be educational. A MediaWise report, summarizing the findings of a number of research studies, states:

Video games are natural teachers. Children find them highly motivating; by virtue of their interactive nature, children are actively engaged with them; they provide repeated practice; and they include rewards for skillful play. These facts make it likely that video games could have large effects, some of which are intended by game designers, and some of which may not be intended. (Walsh et al, 2004)

Educational computer games have been on the market for many years, and potentially they are capable of replacing or supplementing traditional lessons in a wide variety of contexts. They can provide an interactive, stimulating learning environment, which benefit students in the classrooms (Virvou, Katsionis, and Manos, 2005). Yet few games are used in classrooms, for several reasons: some teachers and parents are reluctant to

accept games as having educational value; information and communication technology infrastructure is often of poor quality; the traditional class schedule is not conducive to learning through gaming; there is a limited number of games that successfully combine attractive characteristics with genuine educational objectives.

The goal of the project discussed in this paper was to design and develop a highly interactive and engaging educational computer environment for children, drawing on computer gaming metaphors to augment history lesson plans in elementary school classrooms. More specifically, the goal was to inform elementary school students about various aspects of life in rural Quebec in the 1890s, and to enable the students to draw comparisons with their own lives. The product introduces students in grade five to visual arts as a gateway to history. A virtual environment was created, in which children can freely move around and interact with virtual characters and objects.

2. Virtual Reality and Virtual Environments

The first use of virtual reality (VR) can be traced back to the Sensorama Simulator in the 1950s (Sutherland, 1965), and in the flight simulator industry. Today, VR is used in a wide variety of applications, including the visualization of engineering concepts in early development stages, training astronauts (Jukka Rönkkö et al, 2006), training in specific domains such as astronomy (Loftin, 1994), and in archaeology (e.g., Kantner, 2000). Although the gaming industry began using VR technology in the 1980s, the *id* software company (http://www.idsoftware.com) was the main catalyst in advancing VR games by creating the hugely popular first-person shooter (FPS) games, *Wolfenstein* and *Doom,* in the early 1990s. While designing fully immersive virtual reality remains prohibitively expensive, desk-top VR products are thriving.

Definitions of the terms VR and virtual environments (VE) are constantly evolving (Wilson, 2006), and at times these two terms have been used interchangeably. We use the clarification proposed by Wilson & D'Cruz (2006): VR refers to a technical system set-up, its hardware and software, whilst VE "is the computer-generated experience of a participant, obtained by and through an interface which engages one or more of our senses but almost always includes the visual sense." In general, a VE experience consists of a sense of being within a three-dimensional space, where the user is involved by interacting with objects, and controlling his/her movements. (Wilson & D'Cruz, 2006).

The application of VR/VE in the educational context has been controversial, and debated in the literature. There remains objections from some educators and developmental psychologists regarding the appropriateness of "virtual" experiences for children (Cuban, 1986; Brooks, 1998). Some researchers have also suggested that there are no clear evidence that VR adds value to children's learning, and experience with other media does not demonstrate any significant effects on learning (Clark, 1994). More recent research, however, may suggest the contrary and that virtual environments may have interesting applications for children. Roussos et al (1999) point to some evidence that demonstrate immersion and presence can have strong motivational impact. VR technologies present opportunities "to experience environments which, for reasons of time, distance, scale, and

safety, would not otherwise be available to many young children, especially those with disabilities" (Roussos, 1999, 247). It has been also shown that students who performed poorly in the classroom benefited most from VR games (Virvou, Katsionis, and Manos, 2005). Champion (2004) argues that the application of VR to cultural heritage can benefit from elements that make 3D games engaging such as "embodiment, cultural embedding, personalised maps, interactive artifacts, dynamic environments, mood, and contextual tasks" (p.7).

3. ENVI

The *Intelligent Virtual Environment: Paintings as Virtual Gateways to Social and Cultural History / Environnement Virtuel Intelligent : l'art comme point d'accès virtuel sur l'histoire culturelle et sociale* (ENVI) is a Heritage Canada funded project designed to introduce primary school children in grade 5 to Canadian cultural history. The virtual environment comprises a representation of a real village, St Hilaire (located about 100 km north east of Montreal, Quebec) in the late nineteenth century, in which a number of "scenes", including a kitchen, a dance, and a farmyard, can be explored interactively by users. The scenes are based on two of the drawings by the Quebec artist, Ozias Leduc [1], that appeared in *Claude Paysan*, a book authored by Ernest Choquette and published in 1899[2]. A secondary goal of the project is to engage students in discourse on art as a historical tool or a gateway to the past.

The two drawings were chosen to represent an indoor and outdoor scene of the village. *The Dance* is set in an inn during the religious festival of Mardi Gras or "Fat Tuesday", the last opportunity for indulgence in food and drink before the season of fasting (Lent). The *Road to the Church*, represents the main thoroughfare in St Hilaire. Virtual environments were constructed based on these two drawings, and developed in monochrome (reminiscent of Leduc's original illustrations, which were drawn in black and white). Figures 1, 2, and 3 show the road to the village and the church, a barn and a house typical of the era, and the dance hall, respectively. The user can move freely in the VEs, although the transition from the outdoor scenes to the dance hall requires an intermediary step. The dance hall is set within an inn, or a *Auberge*, a two-storey building with several rooms, a dining hall, and a kitchen. The virtual village comprises several buildings, including a church, some of which can be explored by the user, whilst others are simple two dimensional drawings.

Several animated characters[3] were developed to create a more engaging experience for users. These characters include a guide to help the user with various tasks, two farmers, a cook, and a maid. The VEs are linked to web sites that can provide additional educational information about life in rural Quebec in the 1890s. The information can be accessed through simple binary menus such as *do you want to know more about this topic: yes / no*. The menus appear on the screen in response to the characters, who can 'speak' to the user in either English or French with a click of the mouse. Although ENVI was designed primarily for grade-five students, these "conversations" can differ according to the grade level of the user (elementary or secondary level). The application delivers a desk-top VE, accessible readily and easily via the Web.

Figure 1. The road to the village

Figure 2. A barn and a house

Figure 3. The dance hall

4. Development and Challenges

In this project, VE is used as an alternative medium to a textbook, a movie, a play, or other media that may be used in an educational context. As such, provides students with information upon which they can construct knowledge. This objective poses several major design challenges. A fundamental challenge is to create a learning object that is interesting, even enticing, for students to explore but at the same time remains focused upon its ultimate educational goals. A second challenge concerns conveying abstract ideas to students. The visual richness of the environment effectively communicates the architecture, tools and utensils, costumes, et cetera that were commonplace at that time in St Hilaire. It is more problematic to present abstract concepts such as women's rights, the role of religion, and child labour laws in this environment without resorting to long monologues delivered by characters that would undermine the interactive, explorative strengths of virtual environments.

While producing a text to meet the pedagogical objectives and competencies is relatively straightforward, developing any type of VE, particularly an educational one, is a complex undertaking. The development cycle of VE production, and best practices used in the industry have been the subject of recent research studies (Wilson, Eastgate, and C'Cruz, 2002), but none has focused specifically on design parameters for children. Creating a VE product such as ENVI involves several steps and includes many components.

1. At the outset pedagogical goals and objectives should be established. These should relate directly to the curriculum of instruction, and to the levels of competencies that are required in a specific domain. We consulted three educators from both elementary and secondary schools to arrive at educational goals.
2. In any project involving human-computer interaction, a user need analysis and an application task analysis should be performed, and alternative technologies should be explored. While preferably children should have been consulted for this project, as in our previous projects (e.g., Large et al, 2006), the lack of time in this twelve-month project coupled with a sense that we had sufficient knowledge of their needs through teachers and the curriculum caused us to forgo this step. During the course of development, we investigated alternative technologies such as animation, digital video, and two-dimensional drawings, for specific tasks, which were then incorporated into the project.
3. Prior to the construction of a VE, a script or a storyline must be developed, similar to that used in creating a motion picture, upon which scenarios then are built. An important step in the production of VEs comprises historical research to ensure the accuracy and authenticity of the final product.
4. The storyline should only be written after all the historical research has been completed. Each scenario in the storyline is related to a specific educational objective, and may consist of scenes, characters, dialogues, and educational content in a text form.
5. With the aid of an artist, each scene is developed into many sketches, forming a storyboard, to depict a precise outline of the environment, and to organize and illustrate the flow of the movements (e.g., Figure 4). More than 200 sketches were produced for ENVI, of which only about a dozen were used in the production of the VEs.

6. Professional writers are employed to write the dialogues for the characters, which are then used by actors to record the actual dialogues.
7. The VEs are derived from the storyboards, and constructed. Various tools are utilized to create realistic 3D environments.
8. Digital characters are developed and their movements are determined based on the sketches from the storyboards. The characters' mouth movements are synchronized with the recorded dialogues. To facilitate accessibility for users with hearing disabilities, subtitles for dialogues are presented at the bottom of the screen as transcripts.
9. Multimedia information, i.e., video and music, are developed and then integrated in VEs to enhance and enrich the environments, and facilitate efficient and effective flow of information.
10. Supplemental materials, including website and PDFs, are produced for teachers to provide background historical information as well as suggestions on how ENVI might be used in classroom instruction.
11. All the information, including the dialogues, are translated into French for developing a bilingual product.

Figure 4: Storyboard

We faced many challenges and obstacles in designing, developing, and producing ENVI.

Challenge I: Pedagogy

One of the objectives of a cultural heritage online application is to efficiently deliver historical information to users. Motivation will undoubtedly have impact on the effectiveness of the application. How does one deliver linear narrative content without boring the user? This issue becomes critical when children are the intended users. A combination of different methods of information delivery was used in ENVI to address this issue.

First, the VEs are designed to be enticing and to encourage students to move through the scenes at their own pace with the aim of exploration (Cobb et al, 2002). On the road to the village, children can investigate various buildings, and the geographical features of this village, and view these from different perspectives. While exploring, they encounter characters representing a spectrum of people, who tell the children about aspects of life in the village.

Second, the VEs are interactive. Roussou (2004) argues for a strong link between interactivity, learning and engagement, and states that virtual reality offers interactivity as one of its essential properties. We embedded in one ENVI scene a highly interactive environment for children, when they enter a typical kitchen and interact with the cook. She has a specific set of tasks for the user to accomplish to help her prepare the supper. The tasks involve in this specific sequence include: (a) picking up a wooden log, (b) carrying the log to the stove, (c) lighting the wood in the stove, (d) closing the stove's doors to prevent smoke from entering the kitchen, (e) fetching a bucket, (f) filling the bucket with water from a pump, (g) carrying the bucket to the stove, (h) and filling the pot on the stove with the water. During this operation, a young maid is working in the kitchen, who with a click of the mouse is able to provide further instructions for the user. The interaction allows children to engage more actively with the environment, and to learn about lack of amenities in the nineteenth century. In another scene users must identify from a range of objects in a room those which genuinely belong in this late nineteenth-century setting and those which are historically misplaced.

Third, supplemental materials are provided for the teachers that can be used in the classroom. These include tasks and questions that children have to complete, with the overall goal of creating a pedagogically sound environment. The tasks and questions also facilitate inquiry-based learning, and the transfer of abstract knowledge without resorting to long texts or monologues by the digital characters.

Challenge II: Technology[4]

When designing a VE to be accessed via the Web, technical constraints stem from hardware and/or bandwidth limitations. The former is usually exemplified by low image fluidity (inadequate refresh rate) when navigating within the virtual scene. Limited bandwidth results in overly long download times and unresponsive applications. In

practice, these force designers to reduce the number of objects and digital characters that users can interact with and the level of photo-realism. A VE scene is made up of objects (mesh) and their covering skins (texture). Data storage and transfer requirements are proportional to the number of individual objects/skins and their complexity. The original kitchen scene in ENVI, for example, consisted of many objects (Figure 4), which collectively required substantial hardware capacity and bandwidth. The complexity of virtual objects is defined by the number of polygons they require; more complexity requires more data storage and transfer. For example, a realistic digital character such as those seen in motion pictures (*Final Fantasy IV*, *Golem in Lord of the Rings*) may use up to thirty thousand (30,000) polygons while a cartoon like character may require only two thousand (2,000). The digital characters in ENVI, were more cartoon like and at the lower end of the spectrum, comprising of a few thousand polygons

The original ENVI storyline required many animated characters, which would have necessitated a significant amount of computing power as well as bandwidth, not to mention an enormous amount of time for development. In the "dance" scene, the original storyline demanded a minimum of eight digital characters simultaneously moving together in dance steps and synchronized with music. We investigated various technologies to arrive at the most efficient and effective solution. In the end we decided to make a professional digital video employing eight actors (four couples) who wore 1890s costumes and performed the dance, with historically authentic music found in the Bibliothèque nationale du Québec. Approximately 45 minutes of video was shot, of which about one minute actually was used in the dance scene. The video was transferred to monochrome to match the VE scene. In addition, rather than rendering digital characters for the opening scene and to save time and accelerate the production, a Flash program was developed to introduce the user to ENVI through a series of scenes comprising animated characters.

Transferring data from a server, across the Internet to the client machine is still much slower that accessing data from a local storage medium. Hence, compromises were essential to complete the project: the number and complexity of objects, including the characters, were reduced. While ideally we strived for producing realistic scenes that children normally prefer (Beheshti et al, 2005; Hanna, Neapolitan, and Risden, 2004), we also recognized that people's physiological response is the same for a cartoon or realistic objects and characters (Rothbaum, et al. 1996).

Challenge III: Time

Our over-arching challenge was time. Due to a variety of unforeseen factors and external constraints, the VEs had to be developed in less than eight months, which meant concurrent implementation of procedures and processes. The work on the VEs began before the specific educational objectives were fully developed, breaching one of the first principals of design. Given that construction of animated characters was extremely time consuming, this stage of production was well underway before the scenarios were entirely written. In order to rush through the scenarios, during one phase of the production more than a dozen research assistants were involved in historical research, scenario writing, drawings, music research, movie and sound production.

5. Conclusion

This is the first phase of the ENVI project. Developing VEs for educational purposes is an iterative process (Wilson, Eastgate, D'Cruz, 2002), where the product has to be tested, modified, tested, and so on. In the second phase of the project, still to be completed, ENVI will be tested with children. Nonetheless, we believe that the product can meet the challenge of delivering cultural and historical information using VR technology. With the assistance of several teachers, pedagogical lessons have been embedded in the virtual environments, that can be used to teach cultural history in elementary schools. The virtual experience is supplemented with background information from websites linked from ENVI, multimedia information embedded in the VEs, and educational tasks provided in downloadable PDFs. This is a constructivist model, where students "actively build their own internal models of the world rather than passively accepting data." (Moshell and Hughes, 2002, p.896). The model includes five main features: contextualized learning, individualized learning; authentic tasks; situated cognition, and non-prespecified content (Cobb et al, 2002). Although these features may not all be equally applicable to every learning situation, the model provides a framework, upon which VEs can be constructed, and evaluation and testing of the product can be based.

In building ENVI, we faced a number of challenges, which can be categorised as *Pedagogy*, *Technology*, and *Time*. Developing appropriate pedagogical VEs within a constructivist framework is plausible. However, relying solely on VR technologies may not be sufficient, and the use of other media in the VEs should be considered. We integrated digital video, music, animation, websites, and PDFs to create an environment that may include the elements of the constructivist model. Technology proved to be another challenge in developing ENVI. Compromises had to be made between high resolution, realistic-looking digital characters, on one hand, and throughput, bandwidth limitations, and resource allocation on the other hand. The final product seems to be a reasonable balance between these factors. *Time* proved to be the biggest challenge for the project. Designing and developing VEs require a considerable amount of time, which we did not have. Efficient and effective project management, under these conditions is of paramount importance, as many stages of the project had to be completed concurrently, and without delay. Finally, we developed a product that may pave the way for future applications of virtual environments in the classrooms.

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[2] http://jydupuis.apinc.org/pdf/choquette1.pdf

[3] The terms *animated characters* and *digital characters* have been used interchangeably throughout this article.

[4] The technology was developed by Virtuel Age International (VAI), a Montreal based company specializing in the application of virtual reality in training. (http://www.virtuelage.com)