Looking at and Through Technology

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1 Introduction

Information and Communication Technologies provide a wide variety of innovations that can be used in education. Multimedia applications as well as the synchronous and asynchronous teaching methods have proven their worthiness; they are well documented and the majority of educators consider them as established instructional methods. But these are not the only technological innovations of educational value. Advancements in computers' technology in conjunction with new pedagogic perceptions bring us close to a turning point as to how we conceive learning process and what tools we use in order to facilitate it. A number of researchers consider Virtual Reality (VR) to be a very promising instructive tool. We embrace this view and we consider VR to be a particularly adaptable, ductile and flexible medium that can be used by almost all learning theories and in every educational environment.

2 Constructivism as a theoretical background for educational computer applications

No one can doubt that learning is a very complex process, but we can easily point out four major factors that participate in it, that are also taken into account in all major learning theories. These are:

1. Theoretical basis, which consists of the main principles of a learning theory.
2. Means of implementation that include educators and tools such as printed material, teaching aids, computers, etc.
3. Students that are the target group of every educational system.
4. External factors such as the social milieu (other students, friends, parents, relatives, and so forth), the environment (school, geographic region and climatic conditions), the period during which the educational process takes place and also political and economical conditions.

The complex relations between the above factors, their interdependences, as well as the many variables that can influence them, render learning a complex and exceptionally delicate process. Due to the above reasons, there are many and sometimes-contradictory theories that attempt to describe learning [1]. What we have to keep in mind is that learning is a dynamic process, which occurs randomly, unpredictably at any place and at any time. Also, learning outcomes are not predictable and certainly not pre-determined.

The learning theory that regards learning not as a "closed" system but as an "open" one is constructivism. Constructivism does not face learning in an objectivistic way, supports that predetermined and foreseeable results do not exist and considers that teaching should encourage and not guide the learner [2]. Jonassen mentions the characteristics that instructive planning must have according to constructivism [3]:

- Provide multiple representations of reality and to avoid simplifications, presenting the natural complexity of the world.
- Provide authentic tasks to students
- Provide instructive environments that support the study of real cases
- Knowledge is constructed in association with the frame and the content that is applied.
- Encourage practices that support reasoning.
- Support collaborative learning and not the competition between students.

Multimedia and hypermedia are the computer applications that satisfy to a large extent the above conditions and allow a non-linear course in teaching, giving students the opportunity to choose their own path. Thus, they are extensively used for the materialization of constructivist perceptions. Yet, multimedia and hypermedia applications have two major disadvantages: i) there are certain limitations regarding the interactions they allow between users and the computer and ii) the environments created by them are fairly simplistic.

3 Virtual Reality

We believe that the cause of the above disadvantages originates from the dependency of these applications in the use of 2-dimensional graphics (2D). For the creation of more complex, more interactive applications that are closer to reality, one has to add a third dimension in them, to use 3D graphics. In this case we enter the realm of another computer technology, called “Virtual Reality”. Virtual Reality (VR) places the user in a synthetic 3D environment without restrictions -same or completely different from reality- where she/he is free to select her/his own path, to freely explore anything, whenever and whichever way he likes. Thus, the user creates reconstructions of the synthetic world that she/he encounters. Learning in such an environment meets all the demands of a constructivist instructive planning.

One of the most powerful characteristics of VR is immersion. It is the phenomenon at which the senses of a user are manipulated in such a way, that she/he thinks she/he is actually present in the virtual world. There is a lot of debate between the experts engaged in VR for the role of immersion [4, 5]. The degree of immersion depends on the devices that are used and it also determines the type of VR (desktop, semi immersive, fully immersive). There are contradictory conclusions regarding the importance of the degree of immersion for the achievement of specific educational objectives. Thus, it is possible that the increased interaction with the virtual environment has the same or greater importance, or that the combination of both factors adds to the particular value of VR. In any case, what is certain is that an application does not need to be considerably modified in order to change the type of immersion in which it belongs.

What seems to be a real problem is the limited number of available educational VR applications. The cause is neither the difficulty in creating them, which sometimes is considerable, nor their failure to have satisfactory cognitive results. The real reason is the cost of such applications and the cost of VR’s equipment. The rule that each next computer generation is cheaper and yet more powerful than the previous one, does not apply in VR. Since VR is based exclusively on 3D graphics, powerful and expensive computers are required. Today a typical VR system (hardware and software) has an elevated cost and the acquisition of a complete VR system is economically unaffordable for the average/typical user [6]. Consequently, the initial high interest has been limited. In addition, the majority of research efforts were focused in certain types of VR (i.e. immersive VR, augmented VR) that required much more expensive equipment.

Recent developments in computers' technology contributed to the rebirth of interest for VR. For example, powerful graphics cards with a reasonable cost equip home computers and certain VR devices are promoted in the market for home entertainment (i.e. i-glasses). These advances make us optimistic that shortly its applications will know a wider spread. The driving force behind these developments is the entertainment industry that continuously seeks ways to attract consumers’ interest. At the same time, there is also a change in the software that is needed for the creation of 3D applications, so that much more popular programming tools are used (i.e. C++, VRML).

4 Hardware issues

In order to further increase the infiltration of VR in education, we must discover ways so that the necessary hardware and software is easily accessible not by few experts in the field, but by as many people as possible, allowing for a great number of its applications to be developed. First of all we have to examine if an advanced home PC can satisfactory execute a VR application. Let us consider a typical VR application, for example a virtual city, set the requirements from the hardware according to the demands of the application and examine if these requirements are met:

- Sound: For the recreation of sound conditions that prevail in a city (i.e. cars that pass over), we need multi-channel, multi-directional sound. Any typical sound card, even the ones embedded in an average cost motherboard, with a 5.1 or 6.1 channels output, complies with Dolby Digital or DTS standards and thus directional sound is not a problem.
- Network: We need the presence in the application of two or more users. So, their computers must have network cards for a LAN connection, or modems for an Internet connection. A typical network card can handle 100 Mbits traffic, which is adequate. On the other hand, only high-speed Internet connections provide the appropriate bandwidth in order to have real-time graphically intense applications. High speed ADSL Internet connections are a common place today, thus users can have access to such applications.
- Display: According to the prerequisites of our scenario a 19” monitor –a typical dimension for most of today's PCs- or a video projector is enough.
- Processing speed-memory: All 3D graphics applications are processor and memory demanding. Therefore, there can be no compromises to the processor speed and the amount of memory. Du-

al core processors equip today's computers and quad core processors are already available. These processors provide more than enough computational power and even complex applications can be seamlessly executed.

- Graphics: As our setting requires, a virtual city has a lot of static (buildings) and moving objects (cars, people, etc), multiple light sources (sun, car and road lights), realistic representation of objects and changing weather and light conditions. Creating and presenting a realistic synthetic environment is the task assigned to a graphics card. Even though developments in hardware technology are constant and significant, there is yet no graphics card capable of producing and at the same time handling such complex scenarios. Consequently, certain tricks have to be used in order to bypass this problem. For example, since high polygon count objects increase the number of calculations made by the graphics card, different models of the same object are used, in relation to their distance from the user. Detailed models appear when the objects are near the user and low polygon count models when the objects are far. Another trick is not to draw and calculate interactions with objects the user cannot see. Whole parts of our virtual city are invisible most of the time. Also, the initial world can be broken in smaller parts that are loaded only when the user “visits” them. The only thing that cannot be compromised is the frame rate. 25fps is the absolute minimum in order to create the sense of smooth and continuing movement, which is due to the after-sensation phenomenon. This value must be achieved even when there is a significant number of objects present in the viewpoint of the user.

We have to admit that no matter what techniques we use, there is always a reduction in the quality of the virtual world that has also a negative effect in the user's sensation of immersion. We must however underline the fact that in a few months period fewer compromises will be necessary due to constant developments in hardware technology.

5 Software issues

The other part of the problem is the software we use for the development of VR applications. One should still have in mind that like our initial hardware requirements, this software must have a reasonable cost, be user friendly and easy to learn, thus enabling its use by as many people as possible. We can distinguish five software categories:

<u>Programming</u>: Creating a virtual world using a programming language requires advanced programming skills. On the other hand, the programmer has the absolute control over the various elements of the application. Among many languages, C++ and VRML are the most popular in creating virtual worlds. The former is a powerful language suitable for all kinds of applications. The later was created exclusively for VR applications and is an open source language. The main disadvantage is that VRML applications are Internet oriented. Due to limitations in users’ bandwidth, VRML 3D models are not detailed ones, frame rates are low, and the realism of the virtual world is also low. Another drawback is that the interface and the whole environment of the browsers that are required in order to view VRML worlds leave a low sense of realism.

<u>Rendered walkthroughs</u>: A rendered walkthrough is a video/film of 3D objects, which are rendered along a pre-defined path. The designer can break the film into many scenes that have small duration. By doing so he can overcome the limitations of the hardware and he can use highly detailed models. The final product though, is not an interactive and explorable virtual world, but more or less a movie.

<u>VR development software packages</u>: from the above categories, programming in C++ provides the most satisfactory solution. However, as we already mentioned, programming skills are necessary. Software houses became aware of this problem and have developed software packages that provide to the designer an ergonomic and windowed environment, while in the backstage the virtual world is compiled in C ++. The main advantage is that a powerful programming language is used and at the same time good knowledge of it is not required. Also, if some features are not provided, the developer can implement the needed features by accessing the programming language and by writing the necessary code. Libraries of ready to use 3D objects and object attributes, which are included within the software package, further accelerate the developing process. There are certain drawbacks though:

- Even though software packages are far more easy to use compared to a programming language, still they are complex programmes; full of features and learning them can take a lot of time.
- Although these programs claim that the minimum requirements for running their applications are that of a typical PC, in reality, complex worlds with a significant size, require sophisticated PCs.

- The cost of acquiring them is considerable.
- None includes all the features a designer would like.
- There are compatibility issues, so that the editing of a virtual world developed with one program is impossible by another.
- Finally, the economic crisis that struck VR software houses during the years 1999-2000 led many of them to bankruptcy and so supporting and upgrading of these programs is problematic, if not nonexistent.

From this short presentation of VR software categories, one can understand that for the creation of interactive VR applications, the use of a software package seems to be the appropriate solution, mainly because of the friendly developing environments they provide. However, cost seems to be an inhibitory factor. Also, choosing among the available packages is not an easy task since many variables must be weighted.

6 3D Games

Minor and major problems seem to hold back the mass development of VR applications. For example, content development software is addressed to expert users and there is still a lot to be done in order to improve hardware performance. Yet there is an area of applications not related to VR, which is capable of providing relatively easy-to-use and cost effective tools for the development of VR applications. This area is 3D computer games -which are the prevailing type of games available today- and specifically “first person shoot them up’s”. The user is in a 3D environment and has a first person view of it. This means that he can only see his hands and parts of his body, as we do in the real word. Most importantly, this 3D environment is highly interactive and can be partially or totally explored since the player has to eliminate a number of “enemies”, solve puzzles and avoid traps in order to “stay alive” and advance to the next level. As we already mentioned in a previous chapter, interaction and exploration of a 3D environment are also the fundamental characteristics of a VR application, which provide its important educational value. These similarities between 3D games and VR applications are not the only ones. There is a number of common characteristics that they share, making the boundaries between the two very difficult to discern. What is also interesting is that in some cases 3D games offer more features than VR applications.

The common characteristics are:

- <u>World</u>. The word is used for describing the area in which all objects reside and all events take place. Usually the world is broken into pieces called “levels” in order to archive better hardware performance and better handling of the world.
- <u>Interactions, triggers, events and scripts</u>. In a 3D game interaction between objects or between objects and the user is materialized using the trigger-event concept. For example when the user touches a door, he activates a trigger, which results in opening it. Though there is no limit to the number of triggers and events, placing and setting their operation requires a great deal of work. Similarly, in VR applications, programming or scripts are used for defining the behaviour of objects and their function is the same as in trigger-event system.
- <u>Non-playable characters</u>. In both types of applications certain objects are used in order to bring the world to life and have predefined behaviours (i.e. cars, people, animals, etc). Their actions are the result of the use of complex automatic trigger-event systems or scripts that also take care of their reactions in case of unforeseen situations (i.e. collision with another object).
- <u>Sound and music</u>. Usually in 3D games sound and music play an important role in creating the game’s “atmosphere”. Anyhow multi-channel sound is supported in both types of applications.
- <u>Degrees of freedom, cameras</u>. The user can look up or down, turn left or right and move forward or backwards. This is called "6 degrees of freedom of movement". She/he can also walk, run or fly and can have first or third person view of the world. All these are the result of a camera placed in front or behind the representation of the user. Cameras can also be placed in other objects, providing different aspects of the world.
- <u>Network support</u>. In a VR application two or more users can be simultaneously present, interact with each other and with the objects. This is also true for 3D games, but in a larger scale. Massive multiplayer games (MMOs) are the most popular type of 3D games nowadays, allowing the participation of even thousands of players. What is important is the way that games handle network traffic. Instead of transmitting graphics and sound, they constantly transmit the coordinates of each player in the world and the world is drawn locally in each player’s computer. Therefore, network traffic is minimal and there is no need for high-speed connections. An interesting side effect

of this method is that the course of the game can be recorded and replayed not as a hard disk consuming video file but as a set of sequential coordinates that uses far less hard disk space. This feature can be very helpful either for research or for educational purposes.
- Ergonomics, special devices. VR applications utilize specialized –and expensive- equipment in order to increase the user's immersion. In games the same applies but not with the use of these devices. Usually just the mouse or few keys from the keyboard are necessary for the complete control of the game. But the player can also use a joystick or a D-pad in order to totally replace the mouse and the keyboard. These devices function quite similar to that of VR navigation devices. Finally, glasses that are used for stereoscopic viewing are the same in both cases.

We think that the differences between VR applications and 3D games are minor and result from the different target groups they are addressed to. Furthermore, it is important to draw attention to the fact that they can be easily eliminated:
- Plot. The general idea in 3D games is to provide players with "missions" that have to be accomplished in order to advance to the next "level". These missions create the plot, the scenario that leads the player to certain actions and in a predefined direction. In essence, games are linear in their plot course, despite the fact that there are some games with random events or different endings. In educational terms this is unacceptable, because it narrows down the choices the user has and contradicts to constructivist concepts. In technical terms, the plot is the result of the trigger-event system. If the user activates specific triggers in a specified sequence in some point of the game, then the scenario advances. Omitting these triggers eliminates the plot. The content developer has to decide if it is appropriate and how to use plot advancing triggers.
- Violence. First person shoot them up's base their commercial success on how impressive the “enemies” the player has to face are and in the variety of the “weapons” the player uses in order to "kill" them. In other words 3D games tend to be extremely violent. But as in plot, violence in a game is a technical matter. It depends on the use of a group of object’s attributes that allow the infliction of damage to other objects. If the damage reaches a predefined value, the object is “killed”. The developer can choose not to give values to these attributes, thus eliminating violence.
- Support. Technical support and documentation are crucial for the development software as well as for the functionality of the application under development. All VR software houses provide technical support for both in many forms (i.e. hot lines, on line help, FAQ, examples, users’ fora, etc). In games, support provided by the software houses is substandard. The difference is that since games are more widespread applications, there are independent fora with thousands of users eager to provide help to those in need.

A fundamental question that has to be answered is how 3D games are created. One way is to use game development software packages. There are several types of such packages and the majority of them have a low or a reasonable cost. Their major disadvantage is that they usually are one step behind hardware and software developments. Also, open source game development software packages totally free of charge do exist. Their major disadvantage is that they are in various stages of development and immature.

The other way is to use the game's editor. In essence, an editor is the software tool that the game company used for the creation of the game. The interesting thing is that editors, most of the time, are included in the game packages. One might wonder for what reason a company would reveal and allow the use of them. The answer is quite simple. It is done in order to extend the commercial life of the game and increase sales. After finishing the game, users can create their own levels and distribute them freely, thus keeping the interest for the game on high levels.

The major advantage of using such tools is that they utilize the latest developments in hardware and software. Learning their use is easier in comparison to VR packages. What we have learned from our own experience in the field is that the users’ fora can provide priceless help, especially when the game is very popular. Finally, some editors are under the open source licence, even though licensing for the commercial use of an editor of a successful game can have an extremely high cost (up to several hundred thousand euros). For all these reasons we believe that the available software packages for the creation of 3D games provide satisfactory and cost effective solutions in the creation of VR applications.

7 Conclusions

As mentioned in a previous chapter, VR applications are compatible with the philosophy of constructivism. However, it would be a very narrow point of view if we state that VR is just a simple tool for implementing perceptions imposed by one and only learning theory. There are specific reasons that allow us this opinion. First of all, the use of VR applications changes the established role the students have, since it gives them an active role in what they learn and in how they learn. Secondly, VR affects immediately the user's senses, thus it acts in the initial phase of the training process, functioning more as “vehicle” of senses, an amplifier of experiences, and not as just as a cognitive tool. This fact renders it independent from educational theories [7]. It is also true that, with minor changes, a VR application can satisfy the characteristics of one or more learning theories. For example, a fully explorable and interactive environment satisfies the concepts of constructivism. By limiting interactions or by placing triggers and events that create a plot, determining this way a pre-arranged course of action, then the same environment satisfies the principles of cognitive theories. Behaviouristic concepts can be satisfied by adding elements of reward to students, such as the number of right answers, with the form of a score. Parts of the application are possible to move to the one or the other direction.

In addition, up until now we did not have at our disposal a single tool that could produce comparable experimental data based upon the perceptions of various learning theories. Each researcher implemented an application having as a basis the pedagogical perceptions of his choice and applied them on a target group. Completely different applications were implemented by other researchers and applied to different target groups. Comparing the results of these applications is a very difficult -if not impossible- task. VR applications allow us to realize the same subject in different ways and combinations. Consequently we have the opportunity of obtaining comparable results.

As for shaping the technical framework, we have set as prerequisite VR applications to be easily accessed and developed by anyone interested. We came to the conclusion that with some adaptations it is possible for an advanced home PC to run such applications. Our major concern is the software that is needed for the development of VR applications. We examined the available solutions and found that the most complemented one is VR development software packages. Important disadvantages though, forced us to seek for a better solution in unconventional areas. What we found out is that “first person shoot them up” games and the tools that are used in creating them have many characteristics that belong to the field of VR. This type of game developing tools has nothing to envy from the sophisticated -and costly- VR development software. Thus, we have already started using such tools with good results.

Since students are accustomed with the use of computers and other electronic devices, the use of a VR environment does not present particular problems. Even if we use specializes VR equipment, these devices are designed in such a way that they are compatible with our actions in the real world. However, it is true that it is very difficult -and economically unadvisable- to equip an entire classroom with such devices. Also, potential health problems [8] during the use stereoscopic viewing glasses and i-glasses make us careful, at least until important improvements take place. The use of common computer peripherals, such as joysticks or D-pads, significantly reduces the cost, without compromising the feeling of immersion.

Contrary to what happened in the past, we are expecting important developments in the field of VR. When it comes to computers, developments need very little time in order to be expressed. Characteristic for the situation is the Moore’s “law” which states that the calculating power is doubled every eighteen months [9]. With this fact in hand and the concrete validation of the pedagogical value of VR, we expect it to play a decisive role in educational technology in the next years.

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19.

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