Virtual Reality and 3D Animation Technologies in Teaching Quantitative Subjects

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Abstract

This paper investigates the use of innovative and technology aided teaching methods, which utilize established learning concepts for the purpose of learning enhancement. The main objective is to explore the possibilities of adopting the leading edge technology of virtual reality with the aim of applying it to quantitative courses.

To test the applicability of the technology, one of the latest 3D programming tools was adopted. The findings demonstrated that Virtual Reality technologies, when supported by established learning and teaching concepts, can play a role in mathematics education.

Keywords: 3D, Virtual Reality, Socratic Method, Learning by Association

Introduction

Technologies such as virtual reality will allow the learners to be a part of the learning materials and play important role in the future multimedia systems. For instance, virtual reality has been utilized in practical areas such as three dimensional (3D) modeling of human genes, physics experiments, surgical procedures and tours of terrestrial and celestial landscapes. For details see:

http://www.easypano.com/p_Virtual_Reality_software.html; and
http://www.iei.uiuc.edu/class.pages/rw2g/virtual.html .

Although the term Virtual Reality (VR) is used for different purposes, the original concept refers to *immersive virtual reality*. The general concept of immersive virtual reality was developed back in the late 80s. In immersive virtual reality, participants interact with a world completely generated by computer which is a virtual replica of the actual subject.

As suggested by Beier (2004), one of the main characteristics of immersive virtual reality is that the environment is a full scale replica of the real world and it relates to human size. Hence, the participants get the feeling as if they are interacting with the real environment or subject.

Immersive virtual reality applications include either real or abstract *worlds*. The human body and mathematical concepts are examples of real and abstract situations respectively. Examples of these situations include:

- Medical students can operate on virtual patients and practise various surgical procedures in an interactive manner;
- An architect can take his/her clients on a virtual tour of the dream home designed, see Easypano (n.d.); or
- Different people at different locations can become part of a team; interact with common objects and environments. They can see each other as avatars (virtual humans), and communicate with each other from their perspectives.

Using virtual reality, we can enter and interact with a world that either does not exist or it is difficult to access due to costs or safety reasons. A virtual environment or object is created by computer and humans can interact with this environment for the purposes of training or experimentation. 3-dimensional virtual reality images are more dynamic compared with the physical models. Virtual reality will be ideal in situations where:

1. Access to the real object or environment is hard or impossible.
2. Using the actual objects is unsafe or poses a health hazard for the user.
3. Obtaining and experimenting with the real object is too expensive.

Imagine the practical applications of virtual reality models in situations where using animal organs can be unsafe and restricted. For instance, *Bovine Spongiform Encephalopathy* (commonly known as the Mad Cow disease) poses a problem with the use of animal brain for dissection experiments. This paper examines the effectiveness of virtual reality in teaching and learning.

Current Research in the Field

The Australian *Commonwealth Scientific and Industrial Research Organisation (CSIRO)* scientists have developed a virtual reality system for teaching medical students. This system allows the medical students to interact with virtual organs as if they were touching and manipulating the real ones. Some of the advantages of this digital model as reported by team include:

- greater depth and more dynamic features compared with textbook illustrations; and
- reusability of the models.

See CSIRO Mathematical and Information Sciences (n.d.).

As suggested by RTI International (2004), a combination of the leading edge technology and educational theory will produce an advanced learning environment which aims to achieve a cost-effective education. It should be noted that the medical applications of virtual reality are not only limited to education. The technology can also be adopted in diagnosing diseases. For instance, colon cancer detection is an area which has been investigated. As reported in the March issue of *Nursing 2004* Magazine (2004), research findings have demonstrated that the *virtual colonoscopy* approach is much more accurate in detecting malignant cases (Pickhardt *et al.*, 2003). *Virtual colonoscopy* uses special X-ray images to assemble and construct a virtual image which is almost a true representation of the colon under investigation.

Testing the Applicability of Virtual Reality in Learning and Teaching

The above-mentioned research projects and their findings have inspired the author to undertake further research into VR based learning and teaching.

A virtual reality multimedia on human anatomy was selected for the purpose of this research project. The product is called *Human Lab* (http://www.3dworld.com/). The Human Anatomy Lab has a lecture mode, which allows the teacher to guide the student. It also incorporates tutorial and quiz modes. The purpose was to test the technology and the media rather than the content. This is one of the reasons why a basic human anatomy application was selected.

The main objective of this study was to investigate the effectiveness of virtual reality in tertiary education. In order to test the medium and the technology involved, it was decided to include both Nursing and Business students. The students were invited to rank their perceptions on a 5 point (Likert) scale for the following 6 different factors:

- How much did you enjoy your VR learning experience?
- How do you rate the speed of your learning experience?
- How do you rate the ease of your learning experience?
- How do you rate the relationship between the learning materials and the real world?
- How do you rate the way VR method helped with your understanding of the concepts?
- Would you like to have VR multimedia incorporated into your learning materials?

These learners were provided with Crystal Glasses so that the presentation of photographic quality and truly three dimensional (3D) images would be possible. In other words an almost real (virtual) presentation of the real objects was presented to these learners. Hence, the learners were able to interact both mentally and physically with the learning materials. The effectiveness of this VR based approach was measured via a survey instrument which consisted of:

- an organised VR tutorial;
- a structured Questionnaire; and
- interview for comments.

A comparison of the preferences and perceptions of these two groups made it possible to assess the teaching effectiveness of the technology on students with different backgrounds. It was found that the combined and separate Weighted Average Index (WAI) values of two group of students on all tested factors were greater than 0.8. This indicates that on average, students, are in between the *agree* and *strongly agree* choices on all learning factors. In fact, the Overall weighted Average Index value was 0.9264 which is very close to one. Hence, it can be claimed that the overall importance of this method was very high in terms of students' learning preferences.

As an extension of the application of VR in quantitative subjects, a latest 3D development environment called *VirtualStage* by Dakine Wave Limited (http://www.dakinewave.com/) was adopted to create simulations of classroom sessions in a realistic manner. As part of this project, various learning situations were created and produced as virtual reality productions. Learning and teaching methods which were adopted in these developments are based on established concepts such as learning by guidance. It would be relevant to provide a background to the concept of learning by guidance before proceeding any further.

This way of learning encourages the learner to construct their own meanings rather than simply memorizing someone else's. The concept of guiding and leading the learner to find out the solution or the right answer to a problem was discussed by Plato (the ancient scholar) almost 2400 years ago. If we analyse Plato's famous "dialogue" Meno, we will realise that Socrates demonstrates to Meno how a mathematically ignorant person solves a geometrical problem through a controlled guidance procedure rather than being told directly.

In the dialogue Socrates conducts his geometrical experiment on one of Meno's retainers who was totally ignorant of mathematics.

In this experiment, Socrates asks the boy to determine the dimensions of a square, which is exactly twice as large as a given square (say, abcd). The boy, eventually, after a series of questions, finds out that the correct solution is obtained by constructing the square (twice as large as abcd) on a diagonal (say, ac) of the given square. See Figure 1 for an illustration.

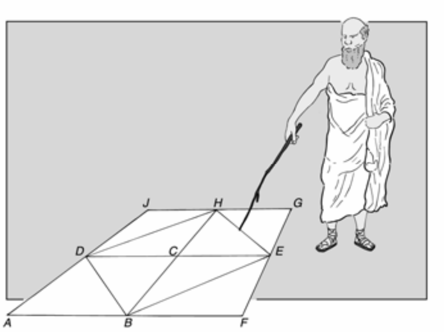

Figure 1 – Socrates pointing to the Square
(Source: The Author)

Even if learning is only the recovery of the pre-existent knowledge in the human soul, as Socrates argues, it can be passed on from teacher to learner by simply guiding the learner to find out for himself.

A series of 3D presentations were developed in VirtualStage. The topics included Decision Theory basics and Introduction to Goal Programming. These presentations demonstrate how the Socratic method of teaching, which usually takes place in a face to face situation, can be simulated, created and captured for replay.

In this presentation, learning is reinforced by the use of specially developed dialogues which is enhanced with audiovisual features. Hence, the user would feel as if they are witnessing and taking part in a real dialogue with the lecturer. Virtual actors play the role of the teacher and students. The people involved and environment are generated by computer and their actions and behaviour are controlled by the designer. All the virtual actors have realistic facial expressions, voices, moving lips, mannerism and movement. They can be viewed in full 3 D from different angles as real actors. These presentations have been deliberately designed in such a way that reliance on text and language-dependent features is kept at minimum. Hence, the learning is re-enforced by the use of specially designed visual and aural features. In these presentations, *Mario* plays the role of a virtual lecturer who adopts the Socratic method of teaching. He engages in dialogues with his students and encourages them to find the answers and solutions through controlled guidance. *Mario*'s appearance, facial expressions, mannerism, speech and lip movements are as close as possible to those of a real person. He, his students and the objects around him are also rendered as 3D. Hence, they can be viewed from different angles and distances as if they are being filmed in real life.

The following dialogue is an example of the adopted Socratic approach between the virtual lecturer (*Mario*) and virtual students (*Sally* and others):

Sally: Mario, we would like to learn the basics of Decision Theory.

Mario: OK. No problem. But, first of all, let me start by asking you: When do you think we have to make decisions?

Sally: When we want to choose the best option out of a number of possibilities?

Mario: Exactly. That is when we are faced with a number of alternatives and?

Sally: And, we are not really sure which one to choose.

Mario: Very good. But, we are sure that we want choose the best one.

As the dialogue indicates, there is a focus on encouraging a questioning, searching and probing mind instead of simply giving the answers. It demonstrates how *Mario* (virtual lecturer) is guiding *Sally* (virtual student) to start thinking along the idea of choosing the best (optimum solution) out of number possibilities (the problem space). And that is the basis of optimization. This kind of controlled and guided questioning approach is continued until the students learn (find out) how to formulate, solve and interpret decision theory problems. In this presentation, the session takes place in *Mario*'s office. The walls of his office are decorated with the image of Socrates. This image (Figure 1) shows Socrates performing his geometrical experiment.

It should be noted that when a teacher utilises appropriate visual and aural features, complements them with appropriate body language and supports everything with effective teaching approaches, then a multimedia-learning environment is created. Provided this teacher is knowledgeable in the field and possesses patience and is prepared to repeat and explain, as many times as necessary, then we would have an ideal learning environment. So, why do we need to simulate this situation as a 3D multimedia? Some of the reasons could be due to:

- **Lack of access to the face-to-face sessions** - Unfortunately, not every student has the opportunity to attend a live face-to-face session. This could be due to distance or commitments in life, which make it difficult for the student to attend the face-to-face sessions. It is noteworthy to mention that the market for tertiary distance education has been growing and will continue to become even larger.

- **Recording and storing the sessions** - A computer-based multimedia teaching material is almost like a movie version of a play. Using computer based multimedia technology (on CD or the Web), we can capture a well rehearsed teaching session, record it and make it available for many students in different geographical locations. The technology can also make it possible for us to simulate some of the teacher-learner interactions too.

In addition to the teaching approach, the learners' modal preferences should also be taken into consideration so that they can have a choice for learning via their preferred styles and senses. Different people learn in different ways. For instance, some prefer listening; some people like reading and others prefer seeing how things are done. It does not necessarily mean that each person must have only one preferred way. Often people have more than one preference. It is a good idea for any leaner to find out about their dominant learning style. There are several types of questionnaires, which can determine the learner's modal preference. Fleming (2001) provides a comprehensive insight into theory and practical uses of learning styles. The chart provided under: *Learning Styles* (n.d.) at: http://www.chaminade.org/inspire/learnstl.htm is an easy and quick method of getting an indication of leaning style preference. The following section provides a brief background to learning by association as adopted in the 3D development project.

Learning by Association

Learning by association is based on associating a new piece of information with a prompter, which will help us with remembering. The prompter can be an image (actual or virtual), sound, object or word. This way of learning is compatible with the general idea of Dual Coding theory proposed by Pavio (1986). According to this theory, by presenting information in both visual and verbal forms the effectiveness of remembering and recalling is improved.

For instance, when it comes to learning the vocabulary of a new language, we may associate a new word with an image or sound with which we are familiar. Every time, we want to recall the new word, we can simply think of the link, which will prompt us to remember the new word. Gruneberg (2002) approaches language learning in a similar manner. However, the images become virtual rather than actual. In other words, the learner is instructed to use their mind's eye to visualize an image related to the segment for 10 seconds. For example, in order to learn the word *valise* (suitcase in French), the learner is asked to visualize the image of suitcases, which are strewn all over the valleys. This is probably more than just the use of the mind's eye as the "mind's ear" is also encouraged to associate the sounding (pronunciation) of the word valise with valeez (valleys). Another interesting example presented by Gruneberg is:

Imagine that you are looking at a plate (in French: *assiette*) and saying to yourself *I-see-it.*

Learning by association can also be applied to remembering and playing melodies on a musical instrument without sight-reading. We can divide the piece into smaller portions and associate them with some appropriate lyrics/words. We can then be reminded of what should follow by listening to the words in our mind's ear. Similarly, using the same approach, we may learn how to recognise various celestial objects in the night sky. We can learn the position and features of some key objects and then use them as the base to learn and remember the positions of less visible and hard to spot objects, (Nooriafshar, 2004).

In mathematics, we can associate complex concepts with analogies. For example to learn the concept of *recursion* in Dynamic Programming, we may use the following analogy: *Imagine yourself standing between two facing mirrors and looking at your reflection reflected several times through the mirrors*. This analogy becomes the basis of a general purpose recursion formula, see Module 3 at: http://www.usq.edu.au/course/material/MGT2102).

The 3D presentations played by our virtual teacher *Mario* in VirtualStage, also adopt features of learning by association in teaching quantitative subjects. An example relates to decision-making under uncertainty. Suppose we have a number of options which yield different outcomes (costs or profits) under different events and we do not know which event will occur. If we wish to select the most promising option, then we may apply either MINMAX or MAXMIN techniques depending on whether we have costs or profits. To remember which one we should apply, Mario suggests that students may understand the concept by remembering the phrase: *Best of the Worst*. In other words if we have costs, select the worst (highest cost) for each option and then choose the best (lowest) of these worst cases. So, in this case we have applied MINMAX. On the other hand, if we have profits, then choose the worst (lowest) profit for each option and finally select the best (highest) of them. Hence, in this case, we have applied MAXMIN.

In order to test the effectiveness of he specially developed 3D presentations, they were demonstrated to a small and selected number of students using the author's laptop. The students were then tested on the topics by asking them several questions. The students answered every question (ten in total) satisfactorily. It should be noted that due to the licensing restrictions on the voices, the productions cannot be distributed via the internet or other means. Hence, it was not possible to test the presentations with distance education students who would probably benefit from this technology. Future developments and progress in this field will probably consider this need.

Conclusion

Visually rich 3D presentations can provide effective teaching and learning environments. A virtual reality multimedia can even further enhance learning by incorporating more realistic images, visual features and dialogue. This combination would lead to a situation where the learners could immerse themselves in the environment and interact with objects and scenarios in a dynamic manner. The studies reported in this paper have shown that simulation of face to face teaching using 3D and virtual reality technologies has certainly a place in tertiary education.

As the technology progresses, it will be possible to simulate classroom sessions which can be enjoyed by all students regardless of their mode of study and geographical location.

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