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Virtual reality and mixed reality for virtual learning environments

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Abstract

This paper explores educational uses of virtual learning environment (VLE) concerned with issues of learning, training and entertainment. We analyze the state-of-art research of VLE based on virtual reality and augmented reality. Some examples for the purpose of education and simulation are described. These applications show that VLE can be means of enhancing, motivating and stimulating learners' understanding of certain events, especially those for which the traditional notion of instructional learning have proven inappropriate or difficult. Furthermore, the users can learn in a quick and happy mode by playing in the virtual environments.

Keywords: Virtual reality; Mixed reality; Cooperative/collaborative; Virtual learning environment (VLE); Edutainment

1. Introduction

Virtual reality (VR) is the use of computer graphics systems in combination with various display and interface devices to provide the effect of immersion in the interactive 3D computer-generated environment. We call such an environment a virtual environment (VE). Research and development into VR and VE applications can be found in many places all over the world.

Mixed reality (MR) refers to the incorporation of virtual computer graphics objects into a real three dimensional scene, or alternatively the inclusion of real world elements into a virtual environment. The former case is generally referred to as augmented reality, and the latter as augmented virtuality. Azuma [1] has defined three characteristics that are integral to an augmented reality interface. Firstly, it combines the real and the virtual. Secondly, it is interactive in real time. Third, it is registered in three dimensions.

VR and MR have been proposed as a technological breakthrough that holds the power to facilitate learning. The research and application of VR/MR technology in education have enriched the form of teaching and learning in current educational strategy. Virtual learning environment (VLE), not only provides rich teaching patterns and teaching contents, but also helps to improve learners' ability of analyzing problems and exploring new concepts. Integrated with immersive, interactive and imaginational advantages, it builds a sharable virtual learning space that can be accessed by all kinds of learners inhabited in the virtual community.

Based on VR/MR techniques, learning action may be processed as following scenery: History students can learn about ancient Greece by walking its streets, visiting its buildings, and interacting with its people. Biology students can learn about anatomy and physiology through adventures inside the human body. The range of worlds that people can explore and experience is

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unlimited, ranging from factual to fantasy, set in the past, present, or future [2]. That is the VLEs' first important task. In the virtual community, learners can model, act and express anything they want as long as the system provides the tool. As an advanced facility toolkit for learning, training and simulation, the principal components of a VLE requires:

- *Knowledge Space* provides integrated learning resource, including the tool that helps to access to learning resources, assessment and guidance.
- *Communication Community* supports general communications, including email, group discussion, web access and social communication.
- *Active Action* functions as the tool for learners that express their active actions. In VLE, learners are not simple knowledge accepters. They are information providers, question askers, question answers and concept analyzers.
- *Facility Toolkit* helps to map of the curriculum into elements (or 'chunks') that can be assessed and recorded, helps to track student activity and achievement against these elements.

In addition, precision of knowledge visualization for learning materials and realistic social interaction among learners are two critical technical factors for building VLEs.

At present, E-Learning shows its power on global learning market. Though lack of immersion factor, it still hits the peak of learning market. Estimated by IDC [3], the E-learning market in 2001 was US$ 5.2 billion and will grow to $23.7 billion in 2006, an increase of 35.6% worldwide. With the application of VR/MR to E-Learning, the market will bloom in the near future.

This paper overviews recent works and applications in several fields related to VLE. Some examples of applying VLE in different fields are presented. Finally, a conclusion is drawn.

2. Virtual learning environments

In this section, we discuss prominent capabilities by analyzing the educational using of VLE. Since VLE is a developing technique in most of the education/training areas, researchers from each of the main communities involved have different starting positions and still, rather different perspectives. Thus, these technologies are far from homogeneous or universally agreed.

2.1. General architecture

VLE provides an environment based on network, and the resources in the network are free to share. Therefore, the study process can enhance the collaboration among learners. The VLE can help learners do cooperative study, and make necessary interactions between each other. For example, ExploreNet [4] is a general-purpose object oriented, distributed two-dimensional graphic-based computational environment with features to support role-playing games for educational purposes, and cooperative learning of many kinds. Among the research works, Prada [5] in his Belife system implements an explicit collaborative mode of utilization. The collaborative mode will challenge learners to share a virtual greenhouse. Each group will be able to alter some environmental conditions parameters to maximize their crop. Liu [6] focuses on Web-based collaborative virtual learning environment. He provides a cognitive learning architecture based on constructivism. The prototype learning system is effective based on the evaluation.

2.2. Human computer interaction

Interaction can promote learners' active learning. During the studying experience, interaction can offer the learner various controls, such as interacting with the virtual environment and manipulating characters or objects in the virtual environment. VLE technologies can address a wide range of interaction capabilities. For example, Maes [7] constructs a video-based interaction with artificial agents called the Alive system. The system is ideally suited to teach users with physical skills, for its convenience to use and immediate feedback. Picard and her affective computing groups [8,9] describe affective wearable computers that are with users over long periods of time, like clothing, and that are therefore potentially able to build up long-term models of users expressions and preferences. The affective wearables offer new ways to augment human abilities, such as assisting the speaking-impaired, and helping remember important information that is perceived.

2.3. Synthetic characters

Synthetic characters with its significant feature of interactive and intelligent behavior can provide a potential tool for learning in VLE. A number of worthy systems and architectures for synthetic character behavior control have been proposed [10–12]. For example, Blumberg and his synthetic character groups focus on developing a practical approach for real-time learning using synthetic characters. Their implementations are grounded in the techniques of reinforcement learning and informed by insights from animal training. They work on building characters that have the everyday common sense, the ability to learn, and the sense of empathy that one finds in animals such as dogs [13] (see Fig. 1).

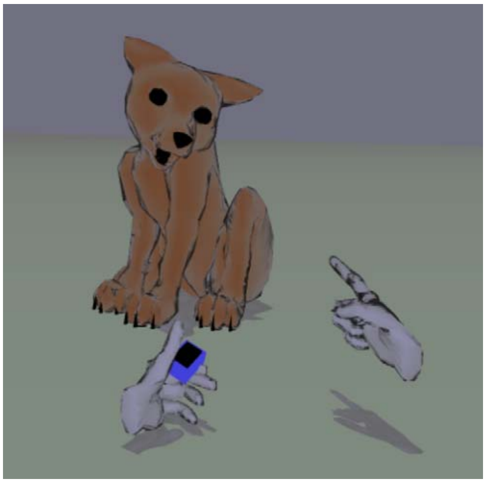

Fig. 1. Terence is an autonomous animated pup that can be trained using clicker training.

Fig. 2. Bosnia scenario [16].

Similarly, USC/ISI developed a pedagogical agent called *Steve* [14,15] that supports the learning process. Agent *Steve* can demonstrate skills to students, answer student questions, watch the students as they perform tasks, and give advices if students run into difficulties. Multiple *Steve* agents can inhabit a virtual environment, along with multiple students. Therefore, it helps to make it possible to train students on team tasks.

At the same time, giving synthetic characters with emotions and personality has a powerful ability to capture and hold students' attention. For example, Gratch [16] designs an immersive training system which models a US soldier carrying out a peace-keeping mission in Bosnia. Every *Steve* agents can be configured with different appearances and voices. Fig. 2 shows the emotional system embodied in the virtual character playing the mother of the child is being used communicate strong emotion to the trainee who has in turn to manage the combination of emotion and reason so as to arrive at a choice of action.

2.4. Storytelling

Storytelling is an effective and important educational mean for children. With the augmented reality (AR) technology, storytelling becomes more and more interactive and intuitive in the sense of human computer interactions. Although AR technology is not new, the potential usage of embedding AR in education is just beginning to be explored.

VLE also fosters the elementary students with the creative and imaginative skills by telling stories. For example, Cavazza [17] builds a Virtual Interactive Storytelling. This should make possible real-time story generation and henceforth user intervention in the storyline. User involvement can take various forms: a user can participate in the story, play the role of an actor, or interfere with the course of action from a spectator perspective (see Fig. 3).

2.5. Psychology and physiology factors on VLE

Tang [18] performs an experiment by studying the survey of 68 students who have participated in a global distance-learning course to conclude the factors that may have influence on the effectiveness in virtual learning environment. Their results reveal students' characteristics, efficacy, attitude towards VLE, technology reliability, media richness and virtual team support relate to the effectiveness of virtual learning. Their results also show that the attitude towards virtual learning is an important predictor for learning effectiveness and that the self-efficacy had more influence on subject effectiveness while technology efficacy predicts more on general effectiveness. Virtual team support is the key to the effectiveness of technology's contribution to learning.

2.6. Integration of learning with entertainment

Funbrain [19] is a website with providing online interactive games according to different levels of

Fig. 3. Interactive storytelling environment.

students and curriculums. This website is divided into six parts: all kid's games, math brain, arcade, parents, teachers, and quiz lab. In the all kid's games part, it provides educational games ranging from one to 12 grades. Math brain part provides many mathematics genre games. Besides the games, parents and teachers parts provide a series of service for parents. Similarly, GameGOO [20] designs games for teaching languages according to the US's students in Grade two. Another well known website is Gamequarium [21]. This website is a search engine for education games. Learning planet [22] is a commercial website, which also provides many didactical games or students.

In China, Researchers of Institute of Software in Chinese Academy of Science designed an amusement park system for children. The software utilizes text, graphics, photos, audio, video, and the latest internet software to create an E-learning environment full of interactive problem-solving exercises to reinforce course materials. This software integrates the entrainment into the education that provides a natural and interesting virtual learning environment. Putting lesson materials in a plot with characters makes these materials interesting and interactive. The children can learn while playing games. This system also uses a pen as the interaction, which can operate easily and directly.

When students follow one of the course stories, they are forced to solve the lesson problems with the characters. This creates an understanding of the lesson material that is deeper and more generalized than learning through rote memorization alone. In order to fully learn an idea or a procedure, students must come to see the nature or the structure of the problem, and they have to do it themselves. Fig. 4 shows two screenshots of the software.

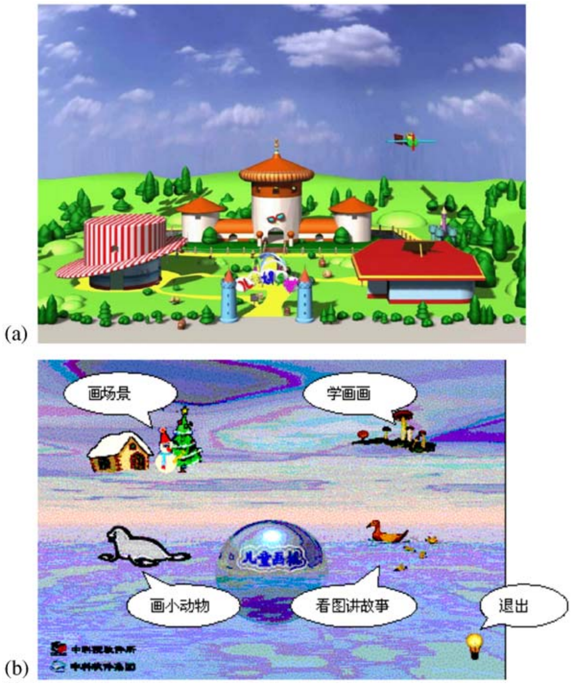

Fig. 4. Two screenshots of the amusement park software. (a) Main interface of the amusement park, (b) The visualized menu.

3. Examples of VR/MR applications designed for learning

Since VLE plays an important role in learning, training and entertainment. In this part, we present some typical examples developed by two groups from China and Singapore.

3.1. E-Teatrix for kids

E-Teatrix is a cooperation result between Zhejiang University and INSEC in Lisbon under the EU-project ELVIS. It is successfully applied to Zhejiang QiuShi elementary school. The aim of Teatrix is to help children around 7 or 10 years old to increase their ability to tell stories. Teatrix is originally developed by INSEC in Lisbon, while E-Teatrix is extended version of Teatrix using in China. It provides a virtual learning environment for children to learn and communicate with each other through a computer interface, therefore it can show them new ways of communication.

E-Teatrix provides students with various vivid and novelty 3D graphical representations of the characters that the children are very familiar with. Children can express what they think and feel through the characters and this stimulates their creativity and imagination. E-Teatrix also provides a collaborative learning environment to stay in the same virtual space. They can team up with each other to enact stories. This collaborative environment fosters in the children adaptability and sociability. In E-Teatrix, there are six basic emotions. Students can input the reason for such emotion. This information helps other students make clear why his character feels the way he does. E-Teatrix also gives these characters different characteristics. For example, they can be bad, helpful, heroic, and magical. Fig. 5 shows some of the characters in E-Teatrix and the types of personalities.

E-Teatrix is used in Qiushi elementary school, and the students' feedback shows that students are satisfied with its contents and teaching methods. The teachers say E-Teatrix strengthens co-operation between all students involved.

Another task in ELVIS project is to apply synthetic characters to behavior training in primary schools [23]. We investigate the potential of VLEs in general and synthetic characters in particular to enhance the school

Fig. 5. Two screenshots of E-Teatrix. (a) Some of the characters in E-Teatrix, (b) Personality of the characters in E-Teatrix.

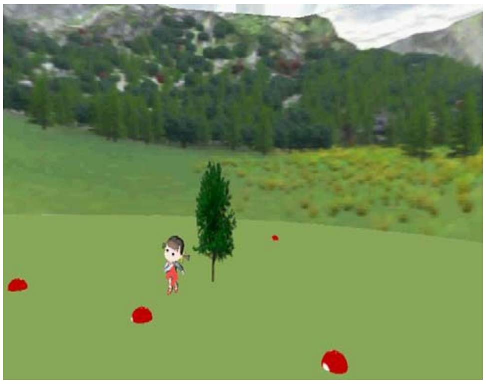

Fig. 6. YY picks up mushroom.

curriculum in China and transfers synthetic character technology into open source form so that it can easily be taken up in Chinese school. As a meaningful supplement to agent system, an open source library AgentLib, is developed for supporting the creation of 3D synthetic characters. Fig. 6 shows an example developed with Agentlib, which is originated from a traditional story called "YY picks up mushroom". In this scenario, YY (a pretty young girl) plays in the ground, picks up mushroom if she finds them, and then she become very happy.

3.2. Sports simulation

3.2.1. Virtual rehearsal system of group calisthentics

As the Olympic Game will be held in 2008 in China, technological Olympic provides a wide testbed for intelligent virtual environment. Zhejiang University and National Gymnastic Bureau develop a formation (or patterns) and virtual rehearsal system of group calisthenics [24]. Group calisthenics is a mass physical training act based on gymnastic motion with the high combination of athletic sports and art. The traditional training depending on the large crowd leads to waste large numbers of manpower and material resources, and the repeated arrangement and training cost more time with low efficiency. To deal with these problems, this system adopts the technology of guided movements of crowds to simulate the transforming process of group calisthenics. The system improves the design quality and efficiency of planning the team pattern and its transforming. Fig. 7 shows the transforming of two patterns.

3.2.2. Virtual bowling game machine

Pan [25] in Zhejiang University designs a virtual bowling game machine called EasyBowling Machine. EasyBowling is an educational model based on techniques such as VR, animation, and image processing for training purposes. Players throw a real bowling ball, and then the EasyBowling system uses a PC Camera to detect the motion of the real ball. After the motion parameters (ball direction, ball force, etc.) are calculated, the movement of the bowling ball and its collision with pins are simulated in real-time and the result is displayed on a large display screen. The most obvious

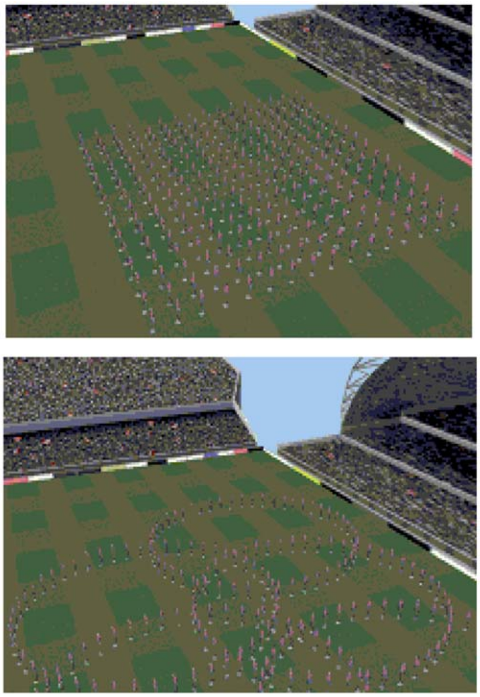

Fig. 7. The transforming of two patterns. (a) Square pattern, (b) Five-circle pattern.

advantage of such bowling game machine is that the system integrates body exercise into game playing and suited to teach users with physical skills. Fig. 8 shows the virtual bowling machine and the simulating results of virtual bowling play.

3.3. Magic story cube—an augmented reality interface for storytelling

In this section, we present a 3D mixed media story cube which uses a foldable cube as the tangible and interactive storytelling interface. Here, we embed both the concept of AR and the concept of tangible interaction. Multiple modalities including speech, 3D audio, 3D graphics and touch are used.

Fig. 9 shows the physical setup of Magic Story Cube. User wears a head mounted display (HMD) with a camera mounted in front to provide the first person viewpoint of the 3D scenes while direct manipulating the process of the story by two-hands interactions [26,27].

In a specific stage, the physical layout of the Magic Story Cube only enables the user to continuously unfold the cube in a unique order. By unfolding the cube, six stages of the story will be unclosed one by one in the order restricted by the cube physical configuration. This physical constraint makes the continuous storytelling possible. As shown in Fig. 9, the unfolding of the cube in a specific stage is unique. This beautifully accords with the continuity requirement of storytelling. Magic story cube applies a simple model of state transition for interactive storytelling.

Fig. 9. Physical setup of 3D story cube: User wears a HMD and views the 3D version of the story through the HMD while exploring the contents of the story by unfolding the magic cube.

(a)

(b)

Fig. 8. Virtual bowling game machine. (a) Prototype (version 2), (b) Simulated results.

Fig. 10 shows the comic strips of the demo in action. Appropriate segments of audio and 3D animation are played in a predefined sequence when the user unfolds the cube into a specific state. The state transition is invoked only after the contents of current state have been played. The state transition is in a one-way manner thus only the first unused story segment will be played back, allowing the story to maintain a continuous narrative progression.

3.4. Mixed reality Kyoto garden

Kyoto in Japan is famous around the world for its unique garden art and culture. Designing a mini sand garden can be a good aid for human mind therapy. However, designing a physical sand table is time consuming, and the white sand can really get messy. To solve this problem, we come out with a novel idea of applying ubiquitous human media approach and develop a virtual garden designing system.

The system layout is shown in Fig. 11. On the table, there will be a base-board consists of 12 different markers. The base-board gives the position of the garden base. On the left, there is a menu board, where a catalogue of three dimensional garden object models is created and displayed on each page of the menu [28,29]. As shown in Fig. 12, to view the virtual gardens and the objects inside, the user needs to hold the HMD and camera, and point to one of the boards (menu board or base-board). If he holds the paddle in front the camera, he will see a virtual wood paddle.

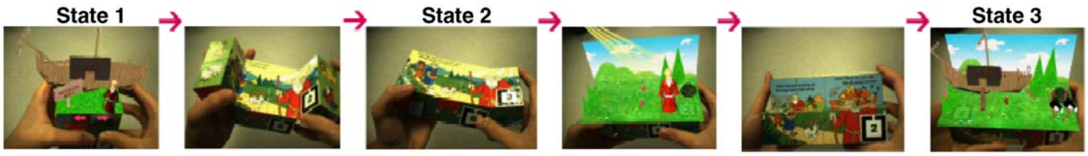

Fig. 10. The one-way state transition of the Magic Story Cube which ensures a continuous narration.

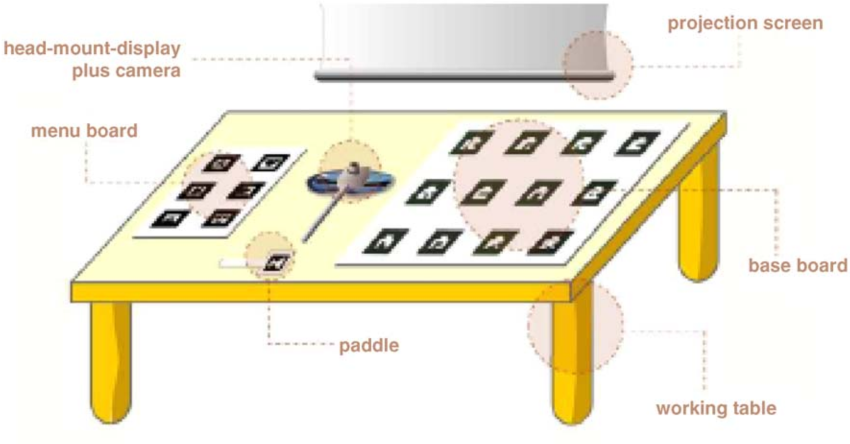

Fig. 11. The layout of the Kyoto Garden system.

Fig. 12. The user holds the HMD, and point to one of the boards to view the virtual garden and menu.

- *Picking up and Dropping*. By pointing the paddle closer to a virtual object on the menu board, the user can pick the object up. After moving the paddle with this virtual object on top to the base-board (White Sand Garden), he can then drop the virtual object on the Table by tilting the paddle to a certain angle relative to the Table surface (Fig. 13).
- *Flipping pages of the menu*. At the left hand bottom of the menu page, there is a virtual button with virtual text ''page change'' on top. Using the paddle to ''hit'' the button gently will change the pages of the ''menu''. Then users can browse through different virtual objects on each page.
- *Scaling of the virtual ponds in the Sand Table*. Pick up the ''scale up'' or ''scale down'' arrow from the menu and move the paddle horizontally closer to the center of the pond in the Sand Table, and then slowly move it away from the center. By doing this, users can easily increase or decrease the pond's size.
- *Moving of the virtual objects in the Sand Table*. Put the paddle parallel to the table surface and about the height of the virtual object which it's going to push. When the paddle is close to the object, a yellow box will appear around the object to indicate that it is in the''push'' mode now. If the user continues to push the paddle, the object will be moved accordingly.

Following the above steps, users can easily select the virtual objects that they are interested and design their own garden. This kind of human computer interaction is a radical departure from scrolling through a list of three-dimensional models on a computer screen. The interface now is the real-world object: a board and a paddle in this case.

4. Conclusion

This paper has given an overview on techniques for VLE, some existing examples of applications where

Fig. 13. Picking up a virtual object from the menu, and drop it to the sand garden.

different aspects of the possibilities of VLE were discussed. From the examples, we can see VLE for education meet the common demands. And VLE supported by VR/MR, as an effective means to update teaching material and innovate teaching methods, will reflect the newest achievement in education field.

Acknowledgements

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