V.O.L.U.M.E. A Web-Centric Database System for building Interactive 3D Constructivist Learning Environments

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Abstract: **Constructivist learning theory postulates that an individual constructs their unique understanding of the world by experiencing, evaluating and incorporating their interpretations into their personal world view. With advances in visual and interactive technologies such as 3-D interactive computer environments, the process of knowledge construction and meaning making from a visual, auditory and kinesthetic perspective can be more fully explored. By creating their own environments, students can develop their own set of objects, relationships and behaviors that are meaningful to them, and that can be shared and experienced by others. By building virtual environments (VEs), students are able to build their own intellectual structures by participating actively and collaboratively.**

V.O.L.U.M.E. is an acronym for Virtual Object Library Universal Management Environment. This paper describes the constructivist theory in education, leading to the design and construction of V.O.L.U.M.E., a web-centric 3D objects database system. V.O.L.U.M.E allows students to shorten the development time for building VEs by using the clip-art concept. Same case studies and examples are shown.

Keywords: **Virtual Environments, Virtual Reality, Constructivist Learning Environment , Database, Interactive 3D Objects**

I. INTRODUCTION

How does a student mature into an intelligent expert? Certainly by studying, but also by undergoing an intellectual apprenticeship, with certain key components. Collis [4] says that the intellectual apprentice must know the tools of his trade, must be able to articulate his perceptions in the language of his profession, and must understand when this language is used well and when it is misused. This partially comes from reading books and listening to lectures, but just as a child learns the ways of his family, not only by observing and studying but by a continual process of trying the language out himself and receiving supportive re-enforcement and correction as he comes to define himself by the norms. In other words, the student constructs and builds knowledge by the process of actively trying out new hypotheses, learning and reflecting from his experience.

Constructivist principles are largely based on Piaget's [12] views that people accommodate new information by reflection on their existing knowledge and finding a place to fit them in. Thus, underlying mental models are used to understand new problems. Learning is considered not just as an individual internal process, but a process where knowledge is shared and built up from social interactions [2]. Constructivist theories suggest that people structure their experiences of the real world, imposing different, individual meanings and perspectives on the same events.

Research into constructivism's contribution to learning leads to the conclusion that students learn more when they invest mental effort in finding and structuring content for themselves, when they take responsibility for building conceptual models that are both consistent with what they already understand amalgamated with the new content, and when they do this collectively with other students (Spiro et. al. [15], Chinn & Brewer [3], Windschitl & Andre [20]). The successful adaptation of old knowledge to new leads to understanding and, when it is the responsibility of students to work at achieving this accommodation, success is also intrinsically motivating.

Furthermore, today, our society expects our school graduates to be able to collaborate, work in teams, teach others, lead and negotiate. They are expected to acquire, interpret, and evaluate data and to have the capacity to learn, reason, and solve problems. It is suggested in Rice & Wilson [13] that constructivism, together with technology will play a large part in the efforts to evolve education to emphasize engaging students in critical thinking, decision making and problem solving.

For the cognitive scientists, learning theorists, instructional designers, and teachers involved in creating constructivist learning environments, learning refers to the development of mental states and abilities of all types including conceptual knowledge, technical skills, automatic rules, mental models and problem-solving. Forms of higher order outcomes such as motivation, intellectual curiosity, and the habits of lifelong learning are especially relevant because these are the most challenging types of learning to teach

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and learn. Jonassen et. al. [8] explained that constructivist environments need to engage learners in knowledge construction through collaborative activities that embed learning in a meaningful context and through reflection on what has been learned through conversation with other learners.

One of the rapidly growing "mindtools" used in constructivist learning environments is that of visualization and graphics [9]. These tools allow students to efficiently reason, interpret and represent ideas visually.

This paper focuses on constructivist learning environments based on VR and the design and application of a web-centric database used to support students' construction of Virtual Environments.

II. CONSTRUCTIVIST LEARNING ENVIRONMENTS USING VIRTUAL REALITY

The potential for developing and experiencing virtual environments, as a learning tool is possible due to our changing educational values as described in section I of this paper. As we come to better understand the nature of human intelligence, creativity, and the value of being multi-modal in our perceptions, there seems to be an increased awareness of developing our students' visual thinking skills in addition to the more traditional focus on reading and writing. Because we can create environments whose properties may have no parallel in reality, we can begin to stimulate students' imagination and visual thinking processes.

When students build virtual worlds, this visual thinking process is clearly demonstrated through the selection and representation of key elements necessary to create meaning in the environment. These elements are displayed both through visual interpretation and through interaction with the environment itself. This opportunity for developing what Gardner [6] terms spatial intelligence can be fostered through virtual environment creation and experience. Mandl and Levin [10], and Willows and Houghton [19] in their separate research showed that the extensive use of graphical symbol systems such as still and animated pictures, simplified visual analogs, schematics, pictorial metaphors and simulations can contribute to learning. Graphics do not require students to use verbal and abstract reasoning skills to construct knowledge, offering alternative routes to success for students who may be weak in these abilities. Also, representing functional relationships by spatial location has been shown to be effective for helping students understand processes, such as how machines operate (Francis & Tan [5], Tan & Ward [16]) and abstract relationships like kinship in families (Winn et. al. [21]). When objects are animated (as they often are in VEs), their behaviour and interactions can be used to illustrate processes that take place over time. In his studies, Rieber [14] demonstrated that computer animation is useful particularly when real or metaphorical motion and trajectory are important concepts. Particularly effective is the animation of objects as a direct result of students' manipulations.

The technology is also used in the education of young children as described in Johnson et. al. [7] where a VE was used for the children to construct and cultivate simple virtual ecosystems and create stories in real and virtual worlds. Andolsek [1] further describes the potential of virtual education environments in the area of special education, architecture, multiculturalism, history, literature, science and mathematics, medicine, corporate training and manufacturing.

In his paper on virtual training environments, Tan [17] describes an initiative taken by the Education Working Group in the Asia Pacific Advanced Network Consortium (APAN). The initiative seeks to provide virtual laboratories over high-speed communication networks using VEs. The projects and experiments in the paper took the concept of VEs further by allowing the users to not only learn and operate equipment in the VEs but also to enable VEs to directly control the physical equipment on-line should the user be allowed to logged onto the training laboratory. Tan suggests that such VEs could be used to augment the learning and training processes with substantial benefits. Tan [18] further elaborates the ideas of distance education via telematics using the principles of constructivism in collaborative and virtual environments using Dale's Cone of Experience as a reference.

Figure 1: Virtual environment

The construction of VEs require students to use a number of strategies that they normally cannot exercise in a traditional classroom, that giving students "ownership" over their own learning is highly motivating and that constructing knowledge for themselves makes what they learn more permanent. For example, Winn et. al. [22] reported that building VEs significantly improved the students' knowledge of factual information and their understanding of the concepts and principles they studied.

However, Osberg [11] indicated that in building VEs, feedback from students showed that 3D modeling was the one area where students faced difficulties and often complained of insufficient time. Students often have to use complicated tools to model objects and these were difficult especially for the younger students and often distract from the main focus, which is to learn content *from* building VEs. Therefore, whilst it is useful for students to build VEs in the learning process, the basic difficulty has always been the 3D modeling component. The idea of the web-database was conceived to simplify this process of modeling from scratch.

III. BUILDING BLOCKS OF V.O.L.U.M.E.

Shortening the life cycle of producing VEs was the main motivator in designing V.O.L.U.M.E. It was also envisaged that it would subsequently enable students to construct VEs at a faster pace by providing search and download capabilities instead of the normal tedious process of modeling the objects from scratch. The objects in V.O.L.U.M.E. should also have the capability of being edited to suit the students' need. It was felt that by so doing, students would be able to learn at a faster pace instead of being bogged down by building 3D models from scratch. This was made possible by providing a huge library of interactive objects, which allow for:

- Accessibility using a web interface
- Searching
- Viewing and Interaction in 3D over the Internet (for selecting object) prior to download
- Downloading in a variety of formats

A. Design

Figure 2 shows the overall design of V.O.L.U.M.E. It is a typical 3-tier architecture. The back-end is a relational database for multimedia data, such as URLs, images, 3D objects and so on. It is much more than just a simple relational data store. Efficient, reliable, secure data management for high-end applications should be supported. It supports Internet computing. The library contains all kinds of 3D objects and images. Behaviors are embedded in the 3D objects for the VEs application.

Middle-tier applications were built to support the system. Both the web server and the database server were placed inside a firewall with only TCP connections to port 80 (the default port number for HTTP). A security check is also added to audit users' actions. As such, only authorized users can modify the specific tables in the database. When a connection request from clients is received, the security application is started. It checks the client information to verify the user ID and privileges. If the user information is valid, a session is created. In this system, there are three user levels, General User, Developer and Administrator. "General User" rights include browsing the images and 3D objects, interacting with the objects and downloading the objects in different formats. As a "Developer", a user can add new objects into the library. The "Administrator" right allows control and management of the library.

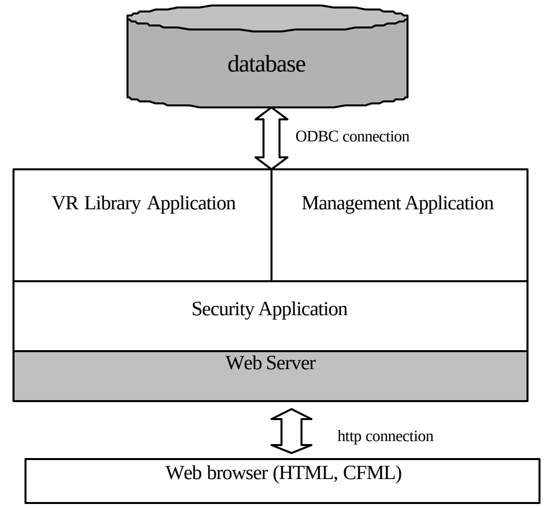

Figure 2: Architecture

The user can use the management interface to control the library remotely while in "Administrator" mode. The management application translates the user's operation into standard Structure Query Language (SQL) and communicates with the back-end database via Open Database Connectivity (ODBC) connections. To add objects, the user only needs to submit the new object location. The system automatically uploads the objects. The records are then inserted into the relative tables in the storage by SQL.

Being web-centric, the system allows students to search the database library from anywhere with a Internet connection. They can search by key words or categories and the system will list all matching objects. Objects can then be selected, viewed from different perspectives and can be inserted into a VE scene. The scene is organized in a tree structure. There are lights and cameras with default values in them. When the student chooses an object, a stream is started between the client and server. The system downloads the object's prototype and attaches it as a node with the scene tree. According to the dimension of the object, the system will recalculate the view-transform, repainting the 3D canvas with the scene camera moving into the proper position. Therefore, the user can watch the VR object from a good vantage point. Students can rotate, zoom and pan in real time to get detail information regarding the object. The features of this solution contain three main factors, no plug-in pre-installation, object independence, and automatic view transformation. This solution is smart, bandwidth saving and object-oriented. Hence, the system makes viewing and downloading 3D objects from the database very convenient for students.

B. Student-Built Examples

The database contains over 2000 different interactive objects in 23 categories. Categories range from plants to animals, house-hold items to electronic equipment and also manufacturing and inventory objects. Figure 3 shows examples from the manufacturing and assembly library. Notice the ease which users can select and manipulate objects using a normal web browser.

Figure 3: User Interface for browsing database

Figures 4 shows a manufacturing line. Figure 5 shows an assembly station in the line and Figure 6 shows an example of a logistic delivery bay. These VEs have been modeled by students of Temasek Engineering School seeking to understand the concept of manufacturing, assembly and supply chain operations of an international computer manufacturer using the database.

In the process of building these VEs, students found that they were able to:

- realize the part-to-whole relationship of the topic they were modeling
- develop an understanding of the manufacturing and logistic operations on a "grander" scale
- be motivated to learn more about the topic
- enjoy building and visiting their VEs
- use the VEs for discussion

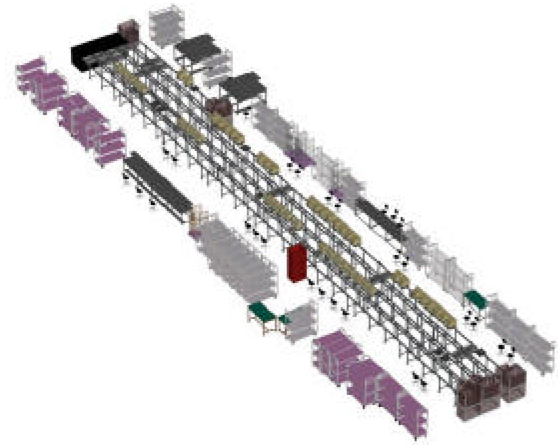

Figure 4: Manufacturing line

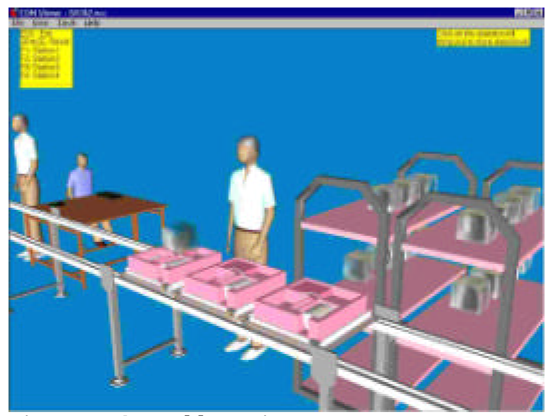

Figure 5: Assembly station

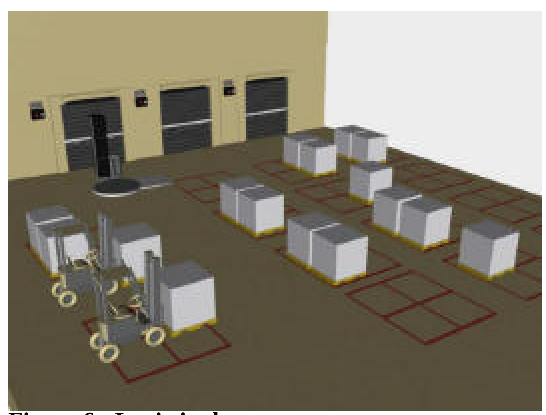

Figure 6: Logistics bay

By using V.O.L.U.M.E., it was found that the VE development time could be generally cut down by up to 20%-50%.

The company that allowed the students to use their factory as a test-bed for the technology found that the VEs built by the students were useful for:

- promoting communication among teams and departments
- improving operational procedures
- training operational personnel
- use as work instructions

IV. Concluding Discussion

Teaching and education have changed to meet the challenges of the 21st Century. The authors believe that the use of virtual environments supports the learning process, the choice and the reception of information, as well as the students' participation in the education process. A virtual environment acts as an experience enhancer and exploits the phenomenon of synaesthesia through which humans experience phenomena via their various senses.

By incorporating the students' creativity, design skills, metacognitive skills, collaborative skills, fact-finding skills, reflective skills and their navigational decisions into the learning process, it is hoped that the students will be provided with a wide avenue for cognitive and affective growth and experience.

In building the web-database, the project team hoped that the task of modeling 3D objects would be made easier for students starting to build VEs.

It was felt that only the tip of the iceberg is being looked at in this paper and that it would be very interesting to see how virtual reality can continue to be used as a learning tool in education.

Acknowledgement

The authors would like to express their gratitude to the National Science & Technology Board (NSTB) and Temasek Polytechnic for funding this research under the project title SERAPHIM (EMT/99/17).

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