

## Virtual Reality on the WWW: Simulating Class I Procedures in Restorative Dentistry

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**Abstract** – The World Wide Web (WWW) is a very efficient way for information exchange. Advancement in web technology now permits visualisation software to be shared across the Internet. This paper discusses the design and prototype development of a web-based VR to create an interactive-simulation for the procedure of a Class I cavity preparation in restorative dentistry. The aim of this research is to find out whether a simple solution utilising the wide accessibility of the World Wide Web (WWW) would be feasible to provide a portable, scalable and low-cost real time dental simulation. To achieve this, a virtual reality simulator, containing simulations of the Class I restorative equipment and materials, is embedded in the webpage. The requirements of a web based VR simulation for this type of application are also discussed.

**Keywords:** *Virtual Reality, Web-based VR, Dental Simulator, Class I Dental Restorative Procedures*

### 1. INTRODUCTION

Technological advancement and changes of oral disease patterns have created a paradigm shift in dental education. One of the many innovations in dental education is the use of information technology, including informatics and operator simulations, to enrich student learning. Virtual reality is an emerging technology that offers great potential for computer based training and simulation. The realistic visual environment, alongside its intuitive forms of interaction, makes VR attractive for a variety of learning and training applications. However, VR is typically associated with powerful graphical workstations and dedicated input/output devices. Thus *utilisation of this technology is restricted by the need for powerful dedicated hardware and systems that are expensive and non-portable.*

In contrast to the expense involved in using available VR systems, web-based VR has the potential to provide a cheap solution with wide availability. The explosion of the World Wide Web (WWW) as an environment for the exchange of information has had a key influence on software development [1]. The unification of the simulation software and of the web

allows distributed simulation applications to be shared among users with internet access. Software developers are targeting the web as an environment for the next generation of applications [2]. This is due to the increasing awareness of WWW's usefulness as a service-provider medium.

The advantage of embedding the VR simulator on the web is the ability to facilitate multi-user access and collaborative working. Moreover, low cost is another attractive feature of this solution. Within limits of the technology being used, this paper presents the design of the prototype development of a web-based VR simulator for learning and training a Class I cavity procedure in Restorative Dentistry. In investigating the practicability of this solution, this research is jointly conducted between the School of Information Technology, University Utara Malaysia and the Faculty of Dentistry of Universiti Kebangsaan Malaysia.

### 2. RESTORATIVE DENTISTRY: AN APPLICATION

Restorative dentistry is that aspect of dentistry involved with the repair of damaged teeth, mainly due to dental caries. Dental caries is a disease of the calcified tissues of the teeth caused by the production of acid by micro-organisms acting on fermentable carbohydrates [3]. The prototype simulates the procedure of repairing a carious lesion on the occlusal or biting surface of a molar tooth. The student diagnoses the lesion, removes the carious tissue and restores the natural shape of the crown.

The goal of the procedure is to remove all dental caries and tooth tissue damaged by dental caries. The shape of the cavity is governed by the amount of caries, by the structure of the tooth substance and the physical and the chemical properties of the material chosen to fill it [4]. This simulation is aimed at training dental students to develop the necessary skills to restore a Class I cavity. The successful completion of the procedure means that the decayed tissue is removed, the cavity is prepared and filled with amalgam and the tooth is restored to its previous natural shape and normal function.

### 3. REQUIREMENTS

When dealing with the dental simulator, realism is a must. There are two types of realism that must be achieved. The first type is realism in terms of accuracy of the modelled objects. Objects created in this simulator consist of the first permanent molar of the lower jaw as well as the dental tools involved in a Class I procedure. A tooth with five cusps must be created with a carious cavity involving the occlusal or biting surface.

Colour, texture and shading of the tooth must be taken into consideration to create a plausible visual representation. Incorrect tooth structure and decay pattern may affect the learning and training objectives. Apart from the anatomy, dental tools must also be created in great detail. This is because each tool has a specific function. Inaccuracy in modelling the tools may create confusion that would make it impossible to perform the tasks correctly. A second type of realism is behaviour realism. This aspect is vital, especially when considering the delivery of real life information. The modelled tooth must behave as far as possible like a real tooth. During drilling, the tooth surface must respond appropriately and break away or disappear. The dental burr must rotate when it is activated and the carver must not bend when carving the hard structure of the amalgam filling material. The simulation must be validated by an expert dentist to verify its accuracy and its feasibility as a learning and training activity.

Apart from the accuracy and behaviour of the 3D models, tasks and skills required to perform the procedure must be identified beforehand. Observations have been carried out to investigate skills that a dentist must possess to complete the Class I cavity preparation. The following classification is based on cognitive skills required to perform each task. Understanding how dentists perform complex tasks can guide the development of the VE and suggest which elements of the simulation are necessary for effective training. The skills and tasks that have been identified are as follows:

*\*Representational skills* refer to an appreciation of the process or object that improves the performance of the task. In this application, students need to be trained to gain the skills required to view the shape of the carious lesion and perform a correct clinical assessment of its extent.

*\*Procedural skills* involve both the cognitive and physical activities needed to perform a series of manoeuvres. These skills also demand that the trainee selects the correct type of instruments for each stage of treatment.

*\*Decision-making skills* are among the most important human skills and are vital requirements for any dentist [5]. Proficiency in making a decision is essential in reaching a correct diagnosis and in formulating an appropriate treatment plan.

*\*Psychomotor skills*, defined as skills in which movement is based on kinaesthetic cues. Dentists rely on touch feedback from the tool tip for diagnosis and positional guidance during the procedures. The skill can be transferred by tactile media, which translates

situations like hitting the surface of the tooth (enamel) into haptic feedback.

### 4. PROTOTYPE DESIGN

Simulation can be defined as the process of modelling a system in such a way that the model mimics the response of the actual system to events that take place over time [2]. Delivering information and building skills via computer simulation is different from the physical manner. As has been mentioned earlier, learning in a physical simulation laboratory is like the training of an apprentice. However, a computer-based simulation approach gives independence to the students so that they can learn in their own time and at their own rate. The big question here is: How to design a simulation that is able to guarantee the success of the skills transfer within the limits of the technology available?

Based on the identified skills associated with the Class I restorative procedure, it is concluded that an ideal restorative procedure simulator should include the following features:

- Real time manipulation of dentistry tools. This feature includes portraying the result of the visual and kinaesthetic interaction (similar to the required eye/hand coordination in a real life situation).
- Graphical media to build the representational skill of anatomy modelling in 3D space.
- Tactile media that give force feedback in response to user action to build the force perception-psychomotor skill.
- Audio feedback to give the effect of drilling and an indication of any errors that occur while performing the procedure.
- Verbal instructions to augment a student's awareness and make the simulation more interesting.
- An environment with a wide range of tooth models and dental tools to practice the decision-making task.

The virtual world provides both a didactic and an experiential learning and training environment. A demonstration mode could give a tour of the intended subject and an exploration mode would allow the student to actually experience the environment [6]. Based on the skills analysis and the technology review, this simulator is divided into two modes namely a demonstration mode and a hands-on learning mode

#### Mode 1: Demonstration Mode

The demonstration mode is based on the apprenticeship model. The purpose of the demonstration mode is to give prior knowledge or an introduction to how the Class I procedure is carried out. Apart from that, it is also intended to give experience to the user regarding how to use the simulator. In this mode, all procedures are simulated automatically as if in a video presentation. However, what differentiates VR simulation from video mode is the real time interaction. Users are given the authority to control the objects and freeze the simulation in the middle of a difficult procedure. At this stage they are

able to search for additional information pertaining to the tasks conducted. In addition to this demonstration, textual information will be provided on the web page and audio instruction will be added to provide additional information.

#### Mode 2: Training Mode

The hands on learning allow users to manipulate the virtual tools and tooth freely. In this mode, users will perform the procedure of Class I independently. Two tasks identified as difficult in the procedure are preparing the cavity outline and carving the amalgam restoration. In this mode, users can repeat any procedures that they think are difficult until they reach perfection. Textual and audio information are available on the web page to help guide the user in doing the procedure.

### 5. IMPLEMENTATION

Building the simulator has involved generating models of a tooth and dental tools, incorporating appropriate user interaction, enhancing the functionality of the 3D page and optimising the application for efficient delivery over the WWW.

The 3D object is created using 3D modeller software. The models are then stored in a library of anatomical models and dental tools so that they can be used in other simulator. Complex models such as the first molar shape contain high polygon counts. This will decrease the rendering and downloading time. Furthermore, the VR authoring tool (Fig. 1) that is used to create the dental simulation can only accept a certain number of polygon counts. Therefore a polygon reduction technique is applied to optimise the process. The feature of the polygon-reduced tooth is then enhanced using the VR authoring software by adding the lit colour attribute. An object's lit colours specify the lightest colour to use for each facet during lighting calculations.

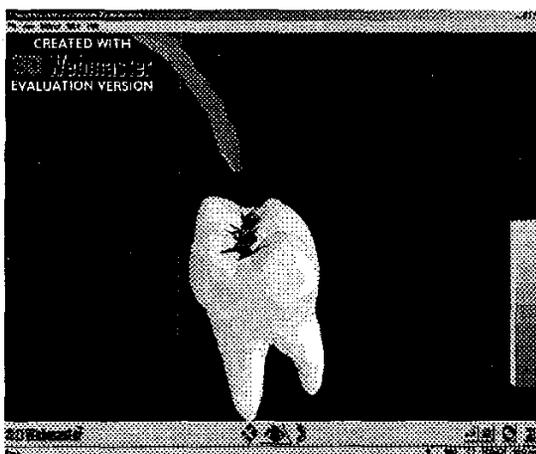


Fig. 1. VR environment created using Superscape 3D Webmaster authoring tool.

The VR authoring tool can only support surface object model. The drilling and scraping procedure requires the tooth to deform to create a cavity. In

creating this procedure on a surface model, the vertex on the occlusal part of the tooth has been defined as dynamic (Fig. 2). With this feature enabled, virtual tooth model can behave accordingly.

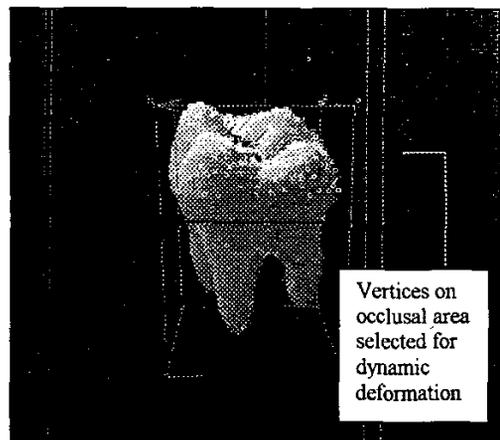


Fig. 2. An object with all vertexes selected.

All skills identified in the previous section have the potential to be easily delivered on a web-based virtual simulation, except for psychomotor skills. This is because standard browsers only support mouse and keyboard and does not other peripheral devices. The use of haptic feedback devices to form force perception is not yet possible on the WWW [7]. Therefore the realism criterion for this purpose is seen as hard to fulfil. Within the limits of the technology being used, alternative sensations, such as audio and visual cues, will be added in order to provide a partial support to this skill.

The user interaction has been designed for a desktop computer utilising a non-immersive virtual environment. In creating a user-friendly environment, the interaction of the objects is designed to be manipulated in a 'drag and drop' manner. An object can be moved around by clicking on it and dragging it around the virtual world using a simple 2D mouse. As the application runs on a WWW platform, the user interface is created to allow interactivity both on the web and the virtual environment. The design of the 3D page has been optimised to include multimedia features.

There has been a growing interest in exploring the utility of the web environment in simulation applications. According to El-Khalili and Brodlie [2], this interest can be classified into two main approaches. First, perform the simulation task on the server and present the result on the client side. Secondly, execute the whole simulation process on the client side, where Java applications and applets are utilised. These systems typically have visualisation processes (pipeline steps) statistically mapped either all on the client side or on the server side (while the client displays the resulting 3D scenes) [8] (Fig. 3).

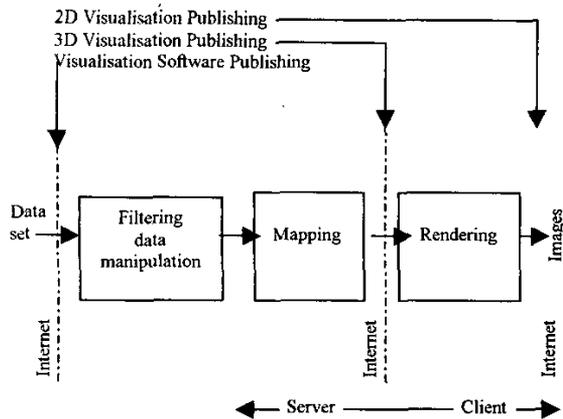


Fig.3. The visualisation pipeline with the Internet [9]

Some web-based systems adopted a “Thin” or “Fat” Client service mode to balance the workload between the user’s workstation and the visualisation server [8]. “Thin” client means most of the visualisation steps are processed at the visualisation server. On the other hand, “Fat” client means most of the visualisation steps are processed at a client workstation.

The development of the simulation in this research employed Fat client solution. Publishing visualisation software greatly reduces the demands put on the server and has the potential for more interactive exploration by tightening the loop between the user and the visualisation system [9]. Embedding the virtual simulator on the web enables large user communities to be accessed. Furthermore, this approach allows the simulator to run on various platforms without being installed locally. The system works by transmitting the software in advance and runs just like Java Applet within a web browser.

## 6. SUMMARY

VR is an emerging technology, which demonstrates great promise in dental education. It allows inexpensive training techniques to be put across the wire. Indeed it has become a framework for distributed computing applications, with user interface provided through the web browser. In particular it has the potential for distributed simulation applications, providing world wide access to the training systems.

The real time or near real time criterion, as well as interactive attributes that VR system possesses, has made it useful for large numbers of applications. The expensive paradigm of VR can be shifted to a more open, accessible and scalable solution by migrating it to the web environment. Providing a world wide access to this technology and building a platform-independent VR application has the potential to create an affordable and accessible solution. Likewise, its applications can be spread to a wider spectrum.

The integration of Internet and VR authoring tool into the desktop configuration have expanded the usage of VR in the classroom and facilitated access to the networked world. The emergence of web-based VR or 3D Page means that a solution to a particular

problem can be utilised and shared with any user having Internet access. There are several reasons why this project is developed on a 3D page. The 3D page is a good place for interactive education purpose. The realisation and visualisation attributes of this new technology have made it suitable for simulating conceptual-based information. It allows learners to explore and perform self-study and facilitates learning through discovery. Students also have the opportunity to explore large quantities of new information since the web page can be linked to many additional resources. Additionally, publishing on the WWW is relatively straightforward, fairly low cost, requires low training needs, is easy to update and has the potential to reach wide audiences. Although it may be some years before the technology is able to contribute to dental and medical education in any significant way, the present-day development of web based VR medical system shows great promise for the future.

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