a sense of touch in online sculpting

Ian Creighton and Dr. Chris Ho-Stuart
School of Information Systems
Faculty of Information Technology
Queensland University of Technology
i.creighton@qut.edu.au

Abstract

This paper describes the work-in-progress of an online multimedia tool employing the sense of touch in exploring and learning sculpting techniques to be used over the Internet. Many game applications use haptic devices as a control mechanism, yet little has been documented on the use of this controlling procedure in an educational setting. The internet based instructional device presented here has a single modeling tool accessed by a customised interface designed with widely accessible software (Macromedia Director MX™). This will be extended to a small suite of modeling tools, in progress at this time. It makes use of a simple force-feedback joystick to control a spherical tool which makes changes to the surface of a 3D model represented onscreen. It is proposed that by using this device with Flash Web Server and the Internet, the system is able to support a collaborative environment encouraging interaction between student and tutor. It is hoped this system will become a research and development tool in online education.

CR Categories: I.3.6 [Computer Graphics]: Methodology and Techniques -- Interaction techniques; K.3.1 [Computers and Education]: Computer Uses in Education – Distance learning

Keywords: Education, Multimedia, 3D, Haptic, Internet.

1 Introduction

Haptic technology facilitates interaction with a virtual 3D object by incorporating the sense of touch into the computer interface. A user is presented with an image of the object on a monitor, and then uses some input device to control a 3D cursor or virtual sculpting tool to modify the geometry of the object. Information on the resistance of the object to the force applied may be conveyed back to the user through the means of force feedback, where the input device gives active resistance to certain motions prompted by the user.

Given a relatively intuitive user interface, students react well to the application of this technology, appreciating the opportunity to interact at a deeper level with a virtual environment.

An existing sculpting tool is the "Sensable Phantom Haptic Pen", shown in figure 1. This is an expensive and sophisticated haptic system often used to pursue academic investigation into haptic theory [Lu et al. 2002] and research projects with art and industry applications [Chen and Sun 2002]. It has six degrees of freedom, which is sufficient to give location and orientation of an object in space.

The Phantom Haptic Pen, (PHP) while being very powerful, is a single user device with a cost putting it out of reach of the common classroom. The PHP was used to scope and identify important features to be included in the Virtual Haptic Sculpting (VHS) prototype.

Figure 1. Sensable Phantom Haptic Pen.

This paper suggests a modification of the technology to provide a simplified, more cost effective version to be offered as an undergraduate or late secondary school application. Its purpose is to generate an experience that stimulates learning through exploration in a hands-on haptic system, delivered over the Internet. Furthermore it will allow collaborative interaction for students and instructors unable to participate in a sculpting studio and may also be used for training and assessment. This work-in-progress will determine if the simpler components suggested for this VHS model will fulfil the necessary requirements to accomplish the sculpting of a 3D virtual object, onscreen in real-time, through manipulation by a commercially available Force Feedback Joystick (FFJ)

2 Background

Using the sense of touch in an educational system is not new [Sankaranarayanan et al. 2003; Richard et al. 2002]. However, this technology, so far, has not been observed to filter down to the wider community as an educational tool.

A major constraint on the widespread use of this technology is simply cost. There have been several attempts to bring the haptic experience into education by using low cost devices [Richard et al. 2002]. One comparatively low cost alternative is to use a force feedback joystick. This has fewer degrees of freedom than the PHP, but it is widely available, and it is already familiar to many computer users, thanks to its use in the gaming territory.

Sculpting instruction in a traditional studio environment relies upon three provisions.

a) A suitable sculpting medium, usually clay.
b) Appropriate tools to undertake specified tasks.
c) Instructional direction from a qualified and/or experienced sculptor in the form of verbal explanation, diagrammatic representation of specific techniques and practical examples demonstrating these techniques.

In this last provision it is seen there are three key processes operating in the classroom. The first is observation to gather the visual information presented. The second is a cognitive mechanism for organising the verbal and visual instructions in a meaningful way. The third is translation of the information into a 3D tangible model interpreted through a tactile or haptic modality.

The role of the tutor in a sculpting studio is to impart knowledge through verbal explanation supported by examples of practical techniques. Existing examples of haptic technology have not been seen to consider these aspects of verbal feedback. This system will attempt to address these shortcomings by specifying faithful transmissions of tactile information with textual/audio prompts across the Human Computer Interface (HCI).

During visits to sculpting classes it was seen that conversations between neighbouring students relating to their work in progress played a significant part in their development. All gained from this communal interaction by sharing existing previously learned and newly acquired knowledge and techniques. Students are also increasingly comfortable with the use of text communications, in messaging systems or on-line chat applications. This project attempts to add a new dimension to interactivity in a dynamic teaching and learning environment by the addition of an online text or voice facility to supplement collaboration already inherent in the design of the prototype.

Simulation of near realistic sculpting techniques relies upon two sources of sensory information; visual feedback and primarily the sense of "feel" or "touch". Recent advances and the lowering of costs of hardware used in haptic technologies have allowed the sense of touch (force-feedback) to be included in car-racing games and flight simulators and other simulations aimed at a broad market through the fast development and implementation of MS ActiveX software developers kit (SDK).

Haptic applications are not limited to the realm of games, engineering, architecture and surgical simulations. They reach into the exploration of teaching and learning tools for the visually impaired. They offer significant interaction with rare works of art not normally accessible to the public.

Lastly, they may be used a creative tool for practising sculptors. Currently, the vast majority of "multimodal" 3D simulations are games.

Investigations in the use of force feedback with the PHP have indicated that force-feedback does not allow students to complete various sample tasks any faster than if the forces were absent. [De Boeck et al. 2001] Responses from students in our survey indicate that they nevertheless appreciate the additional dimension to their interaction with the object.

It is believed this technology may be used as a powerful learning tool when applied to an environment offering collaborative interaction over the Internet. Since all discreet stages of the modeling process are stored in a database there will be a considerable advantage in using this system. All modeling sequences may be replayed any number of times to improve original techniques and patterns are able to be discerned in the modeling process. Present in this system but absent from any real-world studio is the ability to undo any action at any stage.

3 Project Description

This project aims to extend student involvement in a 3D interactive environment by introducing the additional modality of touch. The tangible output of this project will be a Virtual Haptic Sculpting (VHS) device employing a force-feedback joystick interfacing with Macromedia Director™. It will simulate a simple yet precise system of haptic input and output responses facilitated by a small suite of modeling tools accessed over the Internet.

A short questionnaire was developed and submitted to a small target audience of ten participants after they had finished operating the PHP.

The subjects were sculpting tutors, practising sculptors and inexperienced sculptors unfamiliar with 3D computerised navigation. Results from this questionnaire were analysed to define an effective modeling tool to be used in the VHS system. The results were used to identify the features, problems and constraints of such a system. This was used to inform the process of building the VHS prototype.

Results from the questionnaire on the PHP identified a number of issues to be addressed in the design of the VHS. The subjects requested the inclusion of an ability to rotate the sphere to make sculpting easier. Rather than overload the FFJ with this additional role, the task of rotating the sculpture has been delegated to a secondary input controller, the standard mouse. The FFJ is thus free to focus entirely on movement of the sculpting tool.

The VHS system has been designed and developed with object-oriented software architecture to facilitate the scaling and modifications which will be introduced over the course of the project. An initial "single user" prototype has been developed and is in the process of being user tested. This testing focuses on the ability of users to achieve pre-identified key tasks. It quantitatively gauges user’s attitude to the VHS interface system. Their responses will be measured and recorded.

The useability results from the initial single user prototype will be used to inform alterations to the VHS system, including the User Interface and any other required modifications to the software. The initial prototype will then be extended into a multi-user system, allowing collaborative interaction over the Internet and subsequent use as an educational tool.

3.1 General System Design

The use of Macromedia Director as a development platform for this project has several advantages for this kind of project. Executable files can be generated for both Windows (WIN32) and Macintosh (MacOS) operating systems.

As the project progresses it will be a relatively simple process to develop the browser compatible version. The Macromedia Shockwave™ browser plug-in and Flash Communication Server Xtra will be employed for web delivery (Figure 2).

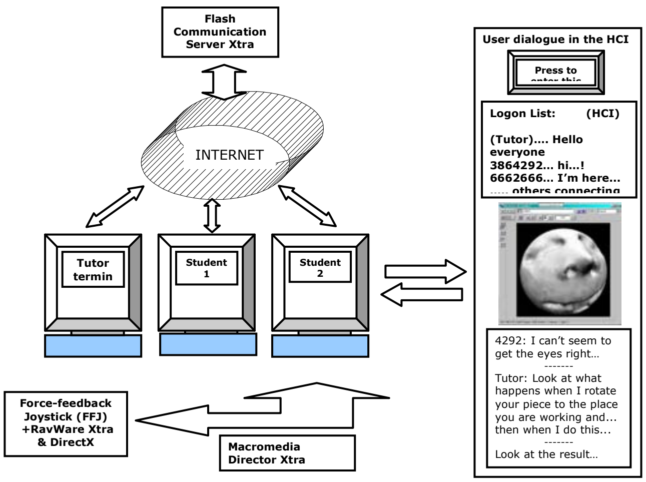

Figure 2. General System Design.

More importantly, the VHS application developed during this project will have no special hardware or software requirements. It is anticipated that only a relatively recent model PC will be required for reasonable performance.

The hardware components used in development of the prototype was a mid range PC. A Pentium III 550 MHz processor with an NVIDIA GeForce4 graphics card and 512Mb of RAM was used for the test system. A Microsoft Sidewinder Force Feedback2 Joystick was employed as the force-feedback input device. A central software component in this system was the RavJoystick Xtra (RJXtra) [Singh 2003].

The API extra was installed as a plug-in to Macromedia Director and using MS DirectX, enabled dynamic control of a customised Director Shockwave interface by the force feedback joystick.

3.2 Force Feedback Module

The figure below illustrates a single user system architecture.

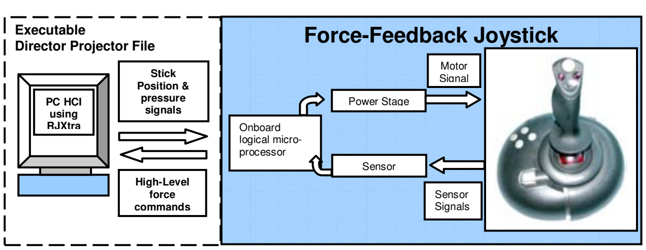

Figure 3. Single User System Architecture.

3.3 Interface Module

The application currently uses a variable sized spherical graving tool. Other tools will be added as future work. The major objective of the application is to allow students to engage and explore the virtual modeling experience rather than to enable development of a complex forms with the use of diverse tools.

A virtual sculpting environment can potentially employ a range of tools limited only by the developer's imagination, such as melting, extruding, painting, peeling, and many others. This is very useful to enable easy development of 3D forms; but it is not necessarily a realistic correspondence to sculpting in real life, where the artist is limited by constraints of the medium.

This application is also constrained by the nature of the hardware used. The PHP is able to simultaneously capture a location and orientation for a tool, but a joystick with fewer degrees of freedom cannot naturally handle both aspects at once. The use of a spherical graver means that there is no need to consider orientations.

The joystick being used has three degrees of freedom. These are the standard motions in the X and Y axis, and also a twist of the handle. There is in addition a slider, which can provide a fourth degree of freedom if required, but for users this is effectively a second device operated simultaneously with the joystick. The force feedback works on the conventional X and Y motions.

The joystick is thus more limited than the haptic pen, but it has the advantage of familiarity from its common use in other contexts and is an intuitive device for students to use.

The system also employs a conventional mouse, which gives a further two degrees of freedom for other operations.

The model for tool movement uses the three degrees of freedom in the joystick to locate the graving tool in 3D space. Pushing forward on the joystick will press the tool into the modelling surface and the force feedback gives resistance to this motion. Moving the stick from side to side swings the tool over the face of the surface following a line which circumnavigates the centre. These two motions define a plane on which sculpting occurs. A back and forth motion moves the tool along a line over the surface of the object, and an in and out motion presses the tool into the object. Finally, this line of motion along which the graver moves is rotated by twisting the handle of the joystick. This allows location of the tool at any point in space, and also gives a natural intuition for the joystick motions.

The X and Y motions of the joystick map to an absolute location for the tool in the sculpting plane, and the twist of the handle sets up a continuous rotation, with the amount of twist governing the speed of rotation. In the normal rest position of the twist axis, the sculpting plane remains at rest. Users who are new to the system take a few minutes to follow how joystick controls the graving tool, and are soon able to control the ball effectively.

The slider on the joystick is used to change the size of the graving tool.

In addition, the conventional mouse is used to rotate the object being sculpted by click and drag. This is a library behaviour supplied with Director MX.

The model object is currently represented internally as a surface. A more sophisticated technique would use volume modeling, which has the potential to give a more realistic approximation to the behaviour of a real life modeling material, like clay [McDonnell and Qin 2002]. However, the surface technique has the advantage of being more computationally efficient, which can be important for operating the software on inexpensive machines.

Macromedia Director provides various lighting models and properties for the reflection of light from a complex surface.

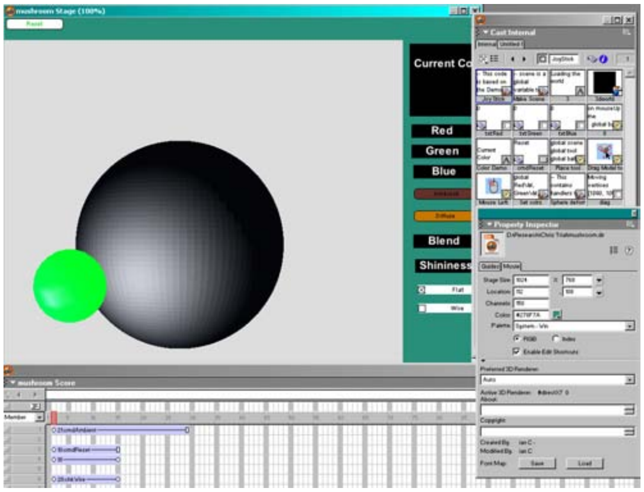

Figure 4. Ball and Graving Tool shown in Flat mode.

Appropriate tuning of these parameters is critical for providing the user of the system with a good three dimensional view of their work. It is also possible to give a wire frame view of the model, as shown in figure 5. The lighting model is based on surfaces and directions to the light source, but not on ray tracing methods. This means that shadows are not represented, but it has the advantage of allowing faster image generation for real time animation. This is essential, because the sculpture itself must be represented with a large number of faces and vertices to have adequate resolution, and continuous response to motions of the sculpting tool requires considerable computation as the model is gradually deformed.

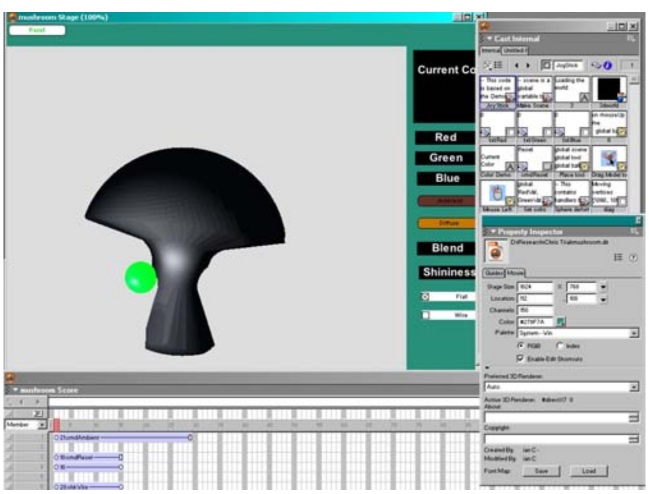

Figure 5. Ball and smaller Graving Tool used for refined modifications. Shown in Flat mode after deformation.

One advantage of the force feedback feature is that it gives more information about the shape of the growing sculpture. Early experience suggests that this helps students to interpret the image presented on a computer screen, letting them feel as well as see the shape of their work. By moving the tool over the surface without activating the modeling action, the force feedback reveals small surface features which are not always easy to see on a computer monitor.

Rotation of the sculpture is important for students to interpret what is seen on the screen and maintain the corresponding mental image of the developing shape. It is possible to use both devices simultaneously, and to make deformations of the sphere while rotating the model beneath the molding tool. However, initial experience suggests that it is more natural to alternate between moving the sphere to a desired orientation with mouse, and then molding it with the FFJ. Most people are naturally right or left handed, and will use their preferred hand for both input devices.

We cannot hope to give the same quantity of information which is naturally available in a real studio, but careful use of available technologies can make the computer abstraction a meaningful one. The initial prototype system can be hard to control, since rapid movement of the tool results in a series of disconnected indentations. The final system will calculate the path of the tool as it is moved and give a continuous deformation all along that path which corresponds to intuitive expectations for a real-life graving tool. Experiments will also continue to explore how to give the most intuitive responses to motions of a joystick, by offering different models for motion of the sculpting tool to users and collecting feedback on their experience.

4 Conclusions and Future Work

The short term goals for this project include the creation of an effective modeling tool with supporting code to facilitate the mesh deformation of a 3D sphere depicted in a stand-alone Director Projector module. Manipulation of the tool is controlled by a force-feedback joystick with haptic information relating to the deformation of the 3D sphere being transmitted back to the joystick. Subjective evaluation of the Virtual Haptic Sculpting device indicates a successful outcome in the simulation of feeling and deforming virtual clay. At the moment the VHS device is a single-user version and since this an ongoing project, work is currently underway to incorporate the Flash Communication Server Xtra to extend its function as a multi-user collaborative Internet tool.

An unexpected similarity in performance was found for novice and experienced subjects. Subjects who were experienced in 3D navigation were comfortable in manipulating the PHP tool and after a short time of familiarisation were successfully navigating through the 3D space. The novice subjects, inexperienced in 3D navigation, found difficulty in orientation yet after a short time, longer than the experienced subjects, were able to successfully navigate in their new environment. There is compelling research evidence from de Boeck et al. [2001] encouraging an extension to these tests. In their more exhaustive experimental setup comparing the levels of usability in three test conditions; a 3D mouse, the Pen with force-feedback and the Pen without force-feedback. It was found "the professionals (experienced 3D users) did not perform significantly any different in the three test conditions. The novice users, on the other hand, showed a significant higher level of skills using the Pen over the other two conditions".

Further investigations will be pursued testing the VHS with experienced and novice users in navigation of 3D space. This will determine if the VHS device, in this particular context, has a significant advantage for persons learning sculpting with little 3D navigational skills.

References

CHEN, H. AND SUN H.Q. 2002. Real-time Haptic Sculpting in Virtual Volume Space, In *Proceedings of the ACM symposium on Virtual reality software and technology*, Hong Kong, China, 81-88.

DE BOECK, J., RAYMAEKERS, C., AND CONINX K. 2001. Expanding the Haptic Experience by Using the PHANToM as a Camera Metaphor, In *Proceedings of the Sixth PHANTOM Users Group Workshop*, CD-ROM

LU, Y. H., WANG, W. T., LIANG, R. H., AND OUHYOUNG, M. 2002. Virtual Sculptor: A Feature Preserving Haptic Modeling System, In *Proceedings of ACM International Workshop on Immersive Telepresence*, Juan Les Pins, France.

MCDONNELL, K. T., AND HONG QIN. 2002. Virtual Clay: Haptics-based Deformable Solids of Arbitrary Topology, In *Proceedings of the Second International Workshop on Articulated Motion Deformable Objects*, Lecture Notes in Computer Science, Springer-Verlag, 1-20

RICHARD, C., OKAMURA, A. M. AND CUTKOSKY, M. R. 2002. Feeling is believing: Using a Force-Feedback Joystick to Teach Dynamic Systems, *ASEE Journal of Engineering Education*, Vol. 91, No. 3, 345-349.

SANKARANARAYANAN, G., WEGHORST, S., SANNER, M., GILLET, A., AND OLSON, A. 2003. Role of Haptics in Teaching Structural Molecular Biology, In *Proceedings of the 11th Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems*, Los Angeles, 363-366

SINGH, R. 2003. RavJoystick Xtra, from *RavWare Software.*