Using Web-Based Computer Graphics to Teach Surgery

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Surgical Training

Surgical training is a long and expensive process. Much of it is done by mentoring, where an experienced surgeon trains a junior colleague - either with the help of models, or on real patients. This is demanding on the time of experienced surgeons, and potentially hazardous for patients. Recently there has been considerable interest in the use of virtual reality approaches to surgical training: these have the potential to allow trainees to work at their own speed, in a fairly realistic way and in a safe environment.

Virtual Environments for Surgical Training

However typical virtual environments for surgical training are:

- dedicated installations using custom-built apparatus, which can only be used in one location
- expensive - often based on Silicon Graphics high-end products
- designed for individual rather than large class teaching
- specific to one type of surgery
- in prototype form as a research exercise rather than in everyday use for training
- lacking in serious evaluation as to the positive transfer of training skills

We have been investigating a different approach. Can we create simple but effective surgical training applications that can be delivered over the Web? These will be VRML worlds which will execute within a Web browser. If we can do this, then the advantages are considerable:

- **accessibility**: the application can be run from anywhere in the world
- **low-cost**: the application can be run from a PC without specialist software (simply a VRML plug-in to a Web browser)
- **distributed**: if powerful computation is required, this could be provided on a remote server, shared between all users
- **class size**: large numbers of trainees can be handled
- **generality**: one could imagine a family of applications, with a consistent methodology, being made available for a range of surgical procedures

Of course - there is a price to pay, namely realism. Can we provide sufficient realism in a Web-based simulation in order to provide useful training?

Applications

We have been collaborating with three groups of surgeons and radiologists at Leeds, in order to investigate the potential of Web-based training. All three applications - while coming from quite different branches of surgery (vascular, neurosurgery, orthopaedic) - require the surgeon to manipulate a tool through the human body. Our approach likewise is common: we convert data from a body scanner into a geometric representation of the part of the body involved, storing this geometry as VRML primitives; we create a geometric model of the surgical tool, again in VRML; and finally we provide some virtual interaction where the user can manipulate the tool through the body. Two of these applications are described below.

Neurosurgery
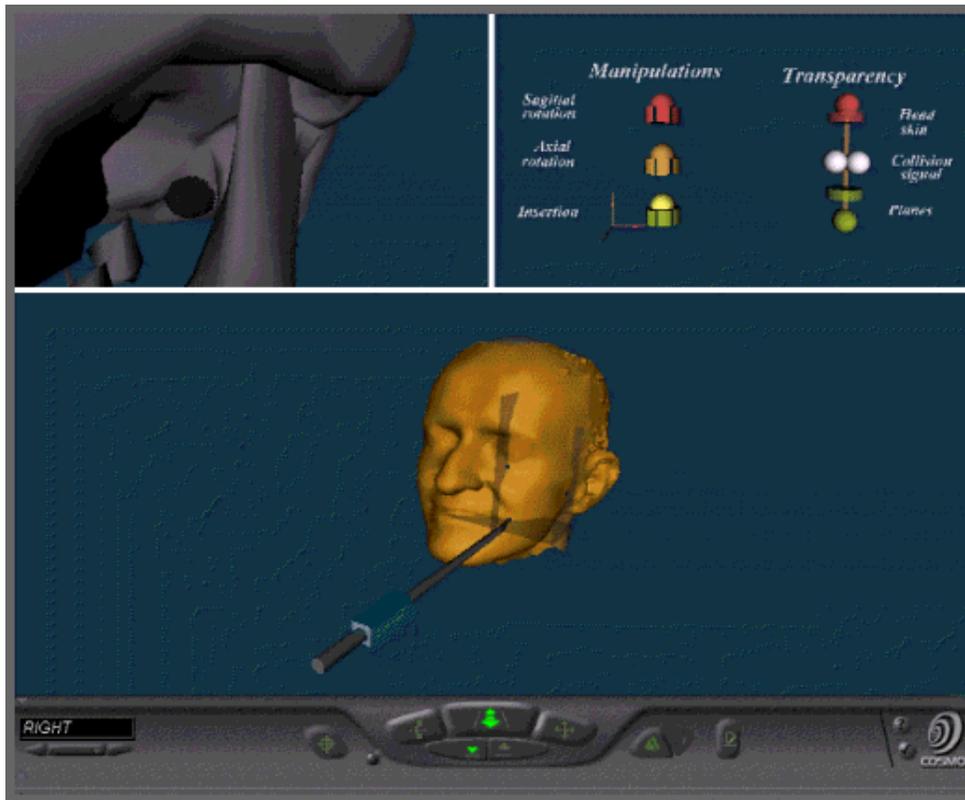
Neurosurgery is a very demanding area of surgery where complex operations are required. These are often composed of a sequence of simpler procedures, with critical decision-taking required in putting the sequence together. If things go wrong, they go wrong quickly and disastrously. This makes it an excellent application area for web-based virtual environment training: the simple procedures can be rehearsed safely, efficiently and inexpensively.
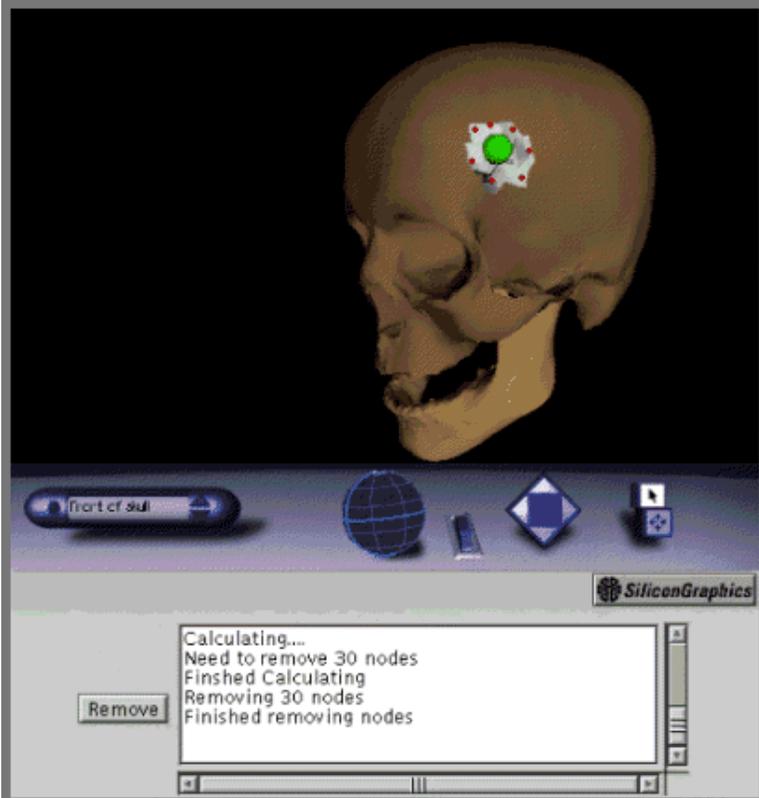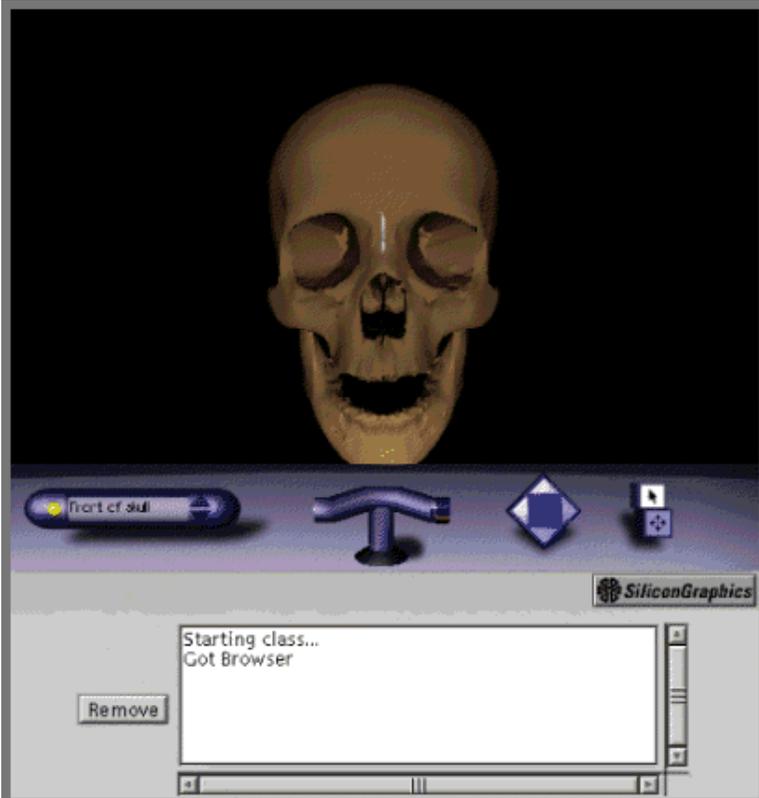
We have developed one simulator for the treatment of intractable facial pain (which if untreated can be so unbearable as to result in suicide). An accepted treatment is Percutaneous Rhizotomy: it is a safe

procedure when performed by experienced hands. Surgeons direct a needle into the medial portion of the foramen ovale, to partially destroy the sensory root for relieving the facial pain. In practice, surgeons mark three points on the patient's face: from these points, a surgeon envisages the coronal and sagittal planes through two of the points, and directs the needle from the third point to the intersection of these two planes.
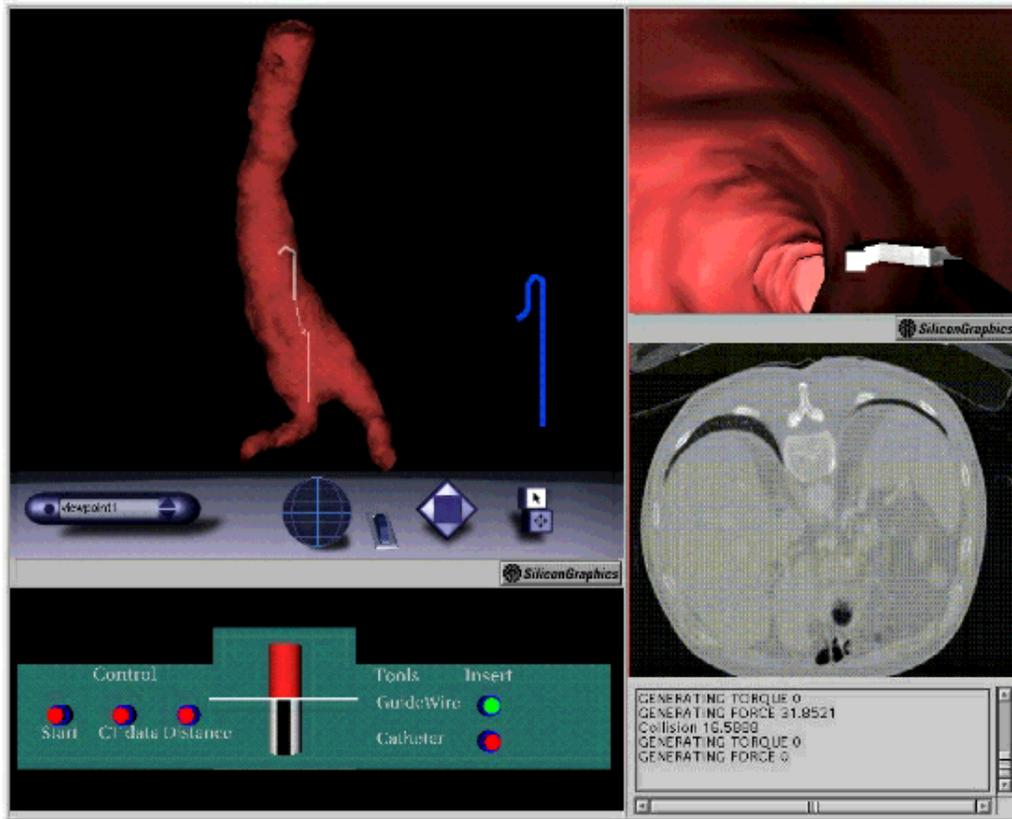
The simulator is shown above. The application is a linked combination of VRML worlds. The skull is modelled in terms of VRML (a large IndexedFaceSet)
and the needle too is a VRML object. The application allows the trainee to mark points on the skull, and insert the needle through the skin, manoeuvring it through a hole in the skull. The coronal and sagittal planes can be highlighted if the trainee needs some guidance (see the picture above). We have used three VRML worlds. One world acts as the control panel, with manipulators that simulate hand operations of the surgeon. The other two give views of the patient: the large view in the lower part of the application is an 'exocentric' view from outside; the top-left gives a more 'egocentric' view, as seen from the tip of the needle. Collision detection is important - but a problem in VRML which supports only viewer-object collision, not inter-object collision which is what is required here. However, we can use the egocentric view to capture collisions, and transmit collision information to all the linked worlds. The linking of the VRML worlds is carried out using the External Authoring Interface (EAI).

We have developed another simulator for craniotomy where part of the skull is removed so that the neurosurgeon can gain access to a brain tumour. In this procedure, the neurosurgeon drills a number of holes in the skull around the area to be removed, and then using a small saw, makes cuts between the holes.

This simulator is shown below. The application is a VRML world with a model of a human skull as a large IndexedFaceSet, with a brain model inside. The trainee can make the skull transparent in order to see the tumour. In the training exercise, the trainee marks points corresponding to the holes to be removed. The simulation then removes the triangles within the area to be cut out, so that the trainee can check the success of the virtual operation.

front of skull

SiliconGraphics

Starting class...
Got Browser

Remove

front of skull

SiliconGraphics

Calculating....
Need to remove 30 nodes
Finshed Calculating
Removing 30 nodes
Finished removing nodes

Remove

Vascular Surgery

Interventional radiology is another complex area where web-based virtual reality has the potential to become an important training aid. In our work we have been looking at a simulation of treatment of abdominal aortic aneurysms. This is a swelling of the aorta; if untreated, the aneurysm may burst causing a critical condition. The treatment involves placing a stent inside the artery to shield it from the anuerysm. This is achieved by inserting a series of guidewires and catheters from an incision in the groin. These instruments are manipulated through the femoral artery, and into the aorta. It is a highly skilled operation, requiring some ten years' training.

The simulation is shown above. It is altogether more complex than the neurosurgical applications because we need to model the deformation of the catheter or guidewire as it collides with the walls of the artery. Again we have a VRML world which contains a model of the aorta and the surgical instruments. Top left shows the exocentric, overall view, top right the egocentric view from the catheter. The lower left area shows an interactor that will push/pull, or twist, the catheter. The lower right shows a CT scan corresponding to a 2D slice through the aorta which can be selected by the trainee.

The system architecture for this application is quite complex. Deformable modelling requires compute-intensive calculation - which may be beyond the capability of the client machine. Thus this application uses a server process to execute the physically-based modelling code which computes the deformation of catheter and guidewire. It also tests for collision between the catheter and artery wall. Communication between client and server needs to be as efficient as possible, since the combined application needs to operate in real-time.

Critical Issues - Interaction, Visual Realism and Haptic Feedback

This is very much work in progress but we now have three years experience and are able to identify the critical issues.

In our approach we rely only on a mouse as physical input device. Mouse movements are mapped to manipulation of virtual input devices in the VRML world - in the neurosurgery application, to simple, generic devices; in the vascular application to a virtual representation of the real catheter. The issue for training is to what extent this can replace the real input device.

We also need to understand the extent to which visual realism is important. In the vascular case, the radiologist has only a mental 3D model of the vascular structure - there is no camera on the end of the catheter. This mental model is constructed from intermittent X-ray images, and from feel - plus years of experience.

Finally, in both applications, haptic feedback is important in the real-life simulation. An expert radiologist can operate almost by touch alone. With simple Web-based tools we cannot provide force feedback (although force feedback mice are soon to be available). However in the vascular case, we have been able to simulate force feedback by colouring the virtual catheter.

Conclusions

We are studying whether simple Web-based computer graphics can help in the training of surgeons and radiologists. We can never hope to achieve the realism of expensive, dedicated VR simulators, but we believe we can create useful tools nonetheless. Through VRML we gain a solution that is both portable and scalable. Moreover we can take advantage of new developments in VRML - such as proposed extensions to multi-user working that could allow collaboration between surgeon and trainee.

The major question to be resolved is the degree of realism that *needs* to be achieved. Perhaps too much realism can be a bad thing! In the area of rendering, there has been a powerful movement in favour of non-photorealistic rendering, where an expressionist style of rendering is used to create a more interesting final result. There may be a parallel in surgical simulation, where the key parameters in the simulation are extracted and presented to the trainee in an 'expressive' style. We would hope to discuss this at the workshop.

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