Virtual Surgery
ABSTRACT

Rapid change is under way on sever fronts I medicine and surgery. Advance in computing power have enable continued growth in virtual reality, visualization, and simulation technologies. The ideal learning opportunities afforded by simulated and virtual environments have prompted their exploration as learning modalities for surgical education and training. Ongoing improvements in this technology suggest an important future role for virtual reality and simulation in medicine.
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1. INTRODUCTION

Rapid change in most segments of the society is occurring as a result of increasingly more sophisticated, affordable and ubiquitous computing power. One clear example of this change process is the internet, which provides interactive and instantaneous access to information that must scarcely conceivable only a few years ago.

Same is the case in the medical field. Adv in instrumentation, visualisation and monitoring have enabled continual growth in the medical field. The information revolution has enabled fundamental changes in this field. Of the many disciplines arising from this new information era, virtual reality holds the greatest promise. The term virtual reality was coined by Jaron Lanier, founded of VPL research, in the late 1980’s. Virtual reality is defined as human computer interface that simulate realistic environments while enabling participant interaction, as a 3D digital world that accurately models actual environment, or simply as cyberspace.

Virtual reality is just beginning to come to that threshold level where we can begin using Simulators in Medicine the way that the Aviation industry has been using it for the past 50 Years — to avoid errors.

In surgery, the life of the patient is of utmost importance and surgeon cannot experiment on the patient body. VR provide a good tool to experiment the various complications arise during surgery.
2. WHAT IS VIRTUAL SURGERY?

Virtual surgery, in general is a Virtual Reality Technique of simulating surgery procedure, which help Surgeons improve surgery plans and practice surgery process on 3D models. The simulator surgery results can be evaluated before the surgery is carried out on real patient. Thus helping the surgeon to have clear picture of the outcome of surgery. If the surgeon finds some errors, he can correct by repeating the surgical procedure as many number of times and finalising the parameters for good surgical results. The surgeon can view the anatomy from wide range of angles. This process, which cannot be done on a real patient in the surgery, helps the surgeon correct the incision, cutting, gain experience and therefore improve the surgical skills.

The virtual surgery is based on the patient specific model, so when the real surgery takes place, the surgeon is already familiar with all the specific operations that are to be employed.
3. VIRTUAL REALITY APPLICATIONS IN SURGERY

The highly visual and interactive nature of virtual surgery has proven to be useful in understanding complex 3D structures and for training in visuospatial tasks. Virtual reality application in surgery can be subdivided as follows:

3.1. Training and Education.
3.2. Surgical Planning.
3.3. Image Guidance.
3.4. Tele-surgery.

3.1. TRAINING AND EDUCATION

The similarities between pilots and surgeons responsibilities are striking; both must be ready to manage potentially life-threatening situations in dynamic, unpredictable environments. The long and successful use of flight simulation in air and space flight training has inspired the application of this technology to surgical and education.

Traditionally, textbook images or cadavers were used for training purposes, the former ie textbook images, limiting one’s perspective of anatomical
structures to 2D plane and the latter, cadavers; limited in supply and generally allowing one-time use only. Today VR simulators are becoming the training methods of choice in medical schools. Unlike textbook examples, VR simulators allow users to view the anatomy from a wide range of angles and “fly through” organs to examine bodies from inside.

The experience can be highly interactive allowing students to strip away the various layers of tissues and muscles to examine each organ separately. Unlike cadavers, VR models enable the user to perform a procedure countless times. Perhaps because of the number of complications resulting from the uncontrolled growth of laparoscopic procedures in early 1990’s many groups have pursued simulation of minimally invasive and endoscopic procedures. Advances in tissue modeling, graphics and haptic instrumentation have enabled the development of open abdominal and hollow-tube anastomosis simulators. Initial validation studies using simulators have shown differences between experienced and novice surgeons, that training scores improve overtime and that simulated task performances is correlated to actual task performances.

Computer-based training has many potential advantages:

- It is interactive.
- An instructor presence is not necessary, so student’ can practice in their free moment.
- Changes can be made that demonstrate variation in anatomy or disease state.
- Simulated position and forces can be recorded to compare with established performance matrices for assessment and credentialing.
• Students could also try different technique and look at tissues from perspective that would be impossible during real operations.

3.2. SURGICAL PLANNING

In traditional surgery planning, the surgeon calculates various parameters and procedure for surgery from his earlier experience and imagination. The surgeon does not have an exact idea about the result of the surgery after it has been performed. So the result of the surgery depends mainly on human factors. This leads to lots of errors and even to the risk of losing the life of the patients. The incorporation of the virtual reality techniques helps in reducing the errors and plan the surgery in the most reliable manner.

The virtual reality technology can serve as useful adjunct to traditional surgical planning techniques. Basic research in image processing and segmentation of computed tomography and magnetic resonance scans has enabled reliable 3D reconstruction of important anatomical structures. This 3D imaging data have been used to further understand complex anatomical relationships in specific patient prior to surgery and also to examine and display the microsurgical anatomy of various internal operations.

3D reconstruction has proven particularly useful in planning stereostatic and minimally invasive neurosurgical procedures. Modeling of deformable facial tissues has enabled simulations of tissue changes and the postoperative outcome of craniofacial surgery. Other soft tissue application includes planning
Liver resection on a 3D deformable liver model with aid of a virtual laparoscopic tool.

3.3. IMAGE GUIDANCE

The integration of advanced imaging technology, image processing and 3D graphical capabilities has led to great interest in image guided and computer-aided surgery. The application of computational algorithm and VR visualization to diagnostic imaging, preoperative surgical planning and interaoperative surgical navigation is referred to as Computer Aided Surgery. Navigation in surgery relates on stereotatic principles, based on the ability to locate a given point using geometric reference. Most of the work done in this field has been within neurosurgery. It also proved useful in Robotic Surgery, a new technique in which surgeon remotely manipulate robotic tool inside the patient body. An image guided operating robot has been developed Lavellee et al, and Shahide et al have described a micro’ surgical guidance system that allows navigation based on a 3D volumetric image data set. In one case, we use intra operative mapping of 3D image overlays on live video provides the surgeon with something like ‘X-ray vision’. This has been used in conjunction with an open MRI scan to allow precise, updated views of deformable brain tissues. Other researchers have focused on applications for orthopedic procedures. Improvements in sensor and imaging technology should eventually allow updates of patient’s position and intra operative shape changes in soft tissues with in reasonable time frame.
3.4. TELESURGERY

Tele-surgery allows surgeons to operate on people who are physically separated from themselves. This is usually done through a master-slave robot, with imaging supplies through video cameras configured to provide a stereoscopic view. The surgeon relies on a 3D virtual representation of the patient and benefit from dexterity enhancement afforded by the robotic apparatus' prototype tele manipulator has been used to successfully perform basic vascular and urologic procedures in swine’s. More advanced system has been used to perform Coronary Anastomosis on exvivo swine hearts and in human undergoing endoscopic Coronary Artery Bypass grafting.

4. VIRTUAL SURGERY SIMULATION

4.1. 3D IMAGE SIMULATION

The first step in this is to generate a 3D model of the part of the body that undergo surgery Simulating human tissues-beit tooth enamel, skin or blood vessels-often starts with a sample from a flesh and blood person that is we should have a 3D model of the part of the body. Using computer graphics we first construct a reference model. Depending on this simulation needed, anatomical images can be derived from a series of patient’s Magnetic Resonance Images (MRI), Computed Tomography (CT) or video recording, which are 2D images. These images are segmented using various segmentation methods like SNAKE'. The final model is obtained by deforming the reference model with constraints
imposed by segmentation results. The image is digitally mapped on to the polygonal mesh representing whatever part of the body on organ is being examined. Each vortex of the polygon is assigned attributes like colour and reflectivity from the reference model.

For the user to interact with the graphics there must be software algorithms that can calculate the whereabouts of the virtual instrument and determines whether it has collide with a body part or anything else. The other thing is, we should have algorithms to solve how it looks or behave when the body part is cut. We need models of how various tissues behave when cut, prodded, punctured and so on. Here VR designers often portray the tissue as polygonal meshes that react like an array of masses connected by springs and dampers. The parameters of this model can then be tweaked to match what a physician experiences during an actual procedure. To create graphic that move without flickering collision detection and tissue deformation must be calculated at least 30 times/sec.

Advances in medical graphic allows ordinary medical scan of a patient anatomy be enhanced into virtual 3D views-a clear advantage for surgeon who preparing to do complicated procedures. Scans from MRJ and CT produces a series of things slices of the anatomy divided into volume data point or voxels, these slices are restacked and turned into 3D images by a computer. These 3D images are color enhanced to highlight, say bone or blood vessels.
4.2. TOUCH SIMULATION

The second step in the simulation of surgery is simulating haptic-touch sensation. Physicians rely a great deal on their sense of touch for everything from routine diagnosis to complex, life saving surgical procedure. So haptics, or the ability to simulate touch, goes a long way to make virtual reality simulators more life-like.

It also adds a layer of technology that can stump the standard microprocessor. While the brain can be tricked into seeing seamless motion by flipping through 30 or so images per second, touch signals need to be refreshed up to once a millisecond. The precise rate at which a computer must update a haptic interface varies depending on what type of virtual surface is encountered-soft object require lower update rates than harder objects.

A low update rate may not prevent a user’s surgical instrument from sinking into the virtual flesh, but in soft tissues that sinking is what is expected. If we want something to come to an abrupt stop that is in the case of bone, etc it requires a higher update rates than bumping into something a little squishy like skin, liver etc.

But still, simulating squish is no easy task either. The number of collision point between a virtual squishy object and a virtual instrument is larger and more variable than between a virtual rigid object and an instrument. Most difficult to simulate is two floppy objects interacting with each other-such as colon and sigmoidoscope, the long bendable probe used to view the colon-because of multiple collision point. In addition, the mechanics of such interaction are complicated, because each object may deform the other.
For simulating touch sensation, we have to calculate the forces applied to cut, prodde, puncture the various tissues. Also how they react or behave when cut, prodded, punctured using surgical instruments. First we have to make physical models of various tissues. The major difficulty in modeling organs is the physical behavior as they have all kinds of complexities—they are anistropic, non homogeneous and nonlinear. In addition, a great deal more physical measurement of tissues will be needed to make realistic haptic maps of complicated parts of the body such as abdomen.

Physical model is made assuming that tissues are polygon meshes that interact like an array of masses connected by springs and dampers. The parameter values are derived using complex nonlinear equations. The reaction forces are also calculated.

In coming years, VR designers hope to gain a better understanding of true mechanical behavior of various tissues and organs in the body. If the haptic device is to give a realistic impression of say pressing the skin on a patient’s arm, the mechanical contributions of the skin, the fatty tissue benefit, muscle and even bone must be summed up. The equations to solve such a complex problem are known, but so far the calculations cannot be made fast enough to update a display at 30Hz, let alone update a haptic interface at 500-1000Hz.
5. WHAT IS A VIRTUAL SURGER SIMULATOR?

The VR simulator basically consists of a powerful PC which runs the software and an interfacer- haptic interfacer- for the user to interact with the virtual environment. Usually the haptic interfacer works on force feedback loop.

The force feedback systems are haptic interfaces that output forces reflecting input forces and position information obtained from the participant. These devices come in the form of gloves, pens, joystick and exoskeletons.

The figure (5.1) shows a haptic feedback loop, how human sense of touch interacting with a VR system. A human hands moves the end effector—shown here with haemostat—of a haptic device causing the device to relay its position via sensors to a computer running a VR simulation.
The computer determines what force should oppose that collision and relays force information to actuators or brakes or both, which push back against the end effector. In the left hand loop, forces on the end effector are detected and relayed to user’s brain. The brain, for example, commands the muscle to contract, in order to balance or overcome the force at the end effector.

In medical applications, it is important that the haptic devices convey the entire spectrum of textures from rigid to elastic to fluid materials. It also essential that force feedback occur in real time to convey a sense of realism.

The rest of the system consists mostly of off-the-shelf components. The haptic device’s driver card plugs into usually a 500MHz PC equipped with a standard graphic card and a regular colour monitor. The software includes a database of graphical and haptic information representing the surgery part. The graphics, including deformation of virtual objects is calculated separately from the haptic feedback, because the latter must be updated much more frequently.
6. PHANTOM DESKTOP 3D TOUCH SYSTEM- A HAPTIC INTERFACER

SensAble technologies, a manufacture of force-feedback interface devices, has developed Phantom Desktop 3D Touch System, which supports a workspace of 6 x 5 x 5 inch. About the size of a desk lamp, the device resembles a robotic arm and has either 3 or 6 degrees of freedom and senses for relaying the arm’s position to PC. The system incorporates position sensing with 6 degrees of freedom and force-feedback with 3 degrees of freedom. A stylus with
a range of motion that approximates the lower arm pivoting at the user’s wrist enables the user to feel the point of stylus in all axes and to track its orientation, including pitch, roll and yaw movement. A number of companies are incorporating haptic interfaces into VR systems to extend or enhance interactive functionality.

The Phantom haptic device has been incorporated into the desktop display by ReachIn Technologies AB. Developed for a range of medical simulation and dental training applications, the system combines a stereo visual display, haptic interface and 6 degrees of freedom positioner. A software package aptly named GHOST, translates characteristics such as elasticity and roughness into commands for the arm, and the arm’s actuators in turn produce the force needed to simulate the virtual environment. The user interacts with the virtual world using one hand for navigation and control and other hand to touch and feel the virtual object. A semitransparent mirror creates an interface where graphic and haptics are collocated. The result is the user can see and feel the object in same place. Among the medical procedures that can be simulated are catheter insertion, needle injection, suturing and surgical operations.
7. IMPORTANCE OF VIRTUAL REALITY IN SURGICAL FIELD

A recent report released by Institute of Medicine in Washington DC, estimates that medical errors may cause 1,00,000 patient deaths each year in US alone. Proponent of virtual reality believes that incorporation of this technology into medical training will bring this grim statistic down.

The main advantages of virtual reality in surgery are:

• Intelligent computer backup minimizes the number of medical ‘mistakes’.

• More effective use of minimal-access surgical technique, which reduces the long length of hospital stays and rest of postoperative complications.

• Better training in anatomy and surgical skill, with reduced need for cadavers.
8. CONCLUSION

Medical virtual reality has come a long way in the past 10 years as a result of advances in computer imaging, software, hardware and display devices. Commercialization of VR systems will depend on proving that they are cost effective and can improve the quality of care. One of the current limitations of VR implementation is shortcomings in the realism of the simulations. The main Impediment to realistic simulators is the cost and processing power of available hardware. Another factor hindering the progress and acceptability of VR applications is the need to improve human-computer interfaces, which can involve use of heavy head-mounted displays or bulky VR gloves that impede movement. There is also the problem of time delays in the simulator’s response to the users movements. Conflicts between sensory information can result in stimulator sickness, which includes side effects such as eyestrain, nausea, loss of balance and disorientation. Commercialization of VR systems must also address certain legal and regulatory issues.

Despite these concerns, the benefits of VR systems in medicines have clearly been established in several areas, including improved training, better access to services, and increase cost effectiveness and accuracy in performing certain conventional surgical procedures.
9. REFERENCE


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