A Seminar Report

on

Virtual Surgery

Submitted in partial fulfillment of the IV B. Tech I-semester (academic year 2022-23) requirements of Jawaharlal Nehru Technological University, Hyderabad.

by

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1. INTRODUCTION

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The use of new technologies is well established for all areas such as industry, medicine, military etc. One of the latest technologies, which have been entering to medicine, is Mixed Reality (MR). Mixed Reality is an integration of real and virtual world. Augmented Reality (AR) is a real environment with some virtual objects, which are augmented in the real world. Virtual Reality (VR) is a technology that allows users to interact with computer-simulated environments. Most current Virtual Reality environments are essential for users to interact with video or audio using tactile sensors.

There is undoubtedly Augmented Reality (AR) can possibly turn into an entrancing across the board engineering in computer Graphics as well as in numerous different other areas. In around 20 years, AR has transformed into a standout amongst the most appealing themes in computer graphics with numerous specialists' researchers to acquire satisfactory results. One of the fastest developing and most strong areas is healthcare area. The virtual reality generated and interesting technology which is called the Second Life. Second Life gave birth of enormous applications in education, business, medicine, and entertainment.

Virtual Reality and virtual environments among the computer simulators for virtual surgery have not been widely sued in professional surgery but they are incorporated into training and education of surgery. Most of professional surgeons believe that this type of technology is very beneficial for surgical education. The main problem is lack of information regarding related virtual reality and augmented reality in the field. The developers of this new technology should focus on training and educator users to figure out this concern. Currently, virtual reality is widely used in medicine most of all for training. In medicine teachers can train students in virtual environments before doing the surgery on real patients

In addition to real surgery and air flight, there are some other fields such as in which nuclear power plant operation, simulators for military and mechanical system maintenance needs virtual reality for training and education. These kinds of fields represent high-risk performance in real actions in which a small failure may face a big result. This tolerance can be ignored in training.

One of the new concepts that recently has been defined is Computational Surgery in which the application of mathematics and algorithm design, enabling imaging, robotics, informatics, and simulation technologies, incorporating biological and physical principles, to improve surgery.

Satava et al proposed taxonomy for virtual anatomy which has been divided into five different generations. A macroscopic level of geometry organs, an accurate detail of physical body, an accurate description of physiology, microscopic anatomy and biochemical systems are the five generation in this taxonomy.

Virtual reality sounds successful in some areas like teaching in leadership skills, airline pilots and mentally challenged. Although, surgery is a high-risk environment, using such technology is using beyond the training too. Surgeons have used virtual reality technology not only in train and educate but also to perform surgery remotely by using robotic devices. Surgeons have utilized virtual reality technology to prepare and teach, as well as to perform surgery remotely by utilizing mechanical gadgets.

Advancements in computing power have enable continued growth in virtual reality, visualization, and simulation technologies. 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. The term virtual reality was coined by Jaron Lanier.

In surgery, the life of the patient is of utmost importance and surgeon cannot experiment on the patient body. Many patients have lost lives because of surgical errors. Virtual reality provides a good tool to experiment the various complications arise during 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. This helps the surgeon to have clear picture of the outcome of surgery. The surgeon can view the anatomy from wide range of angles. 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.

Virtual surgery is very useful when dangerous surgery is performed without harming anyone. It can be done on computer screen with motion sensors. In general, there are two types of surgery, that are traditional surgery and laparoscopic surgery. Traditional surgery is risky than the Laparoscopic surgery.

2. VIRTUAL SURGERY

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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.

In case of virtual surgery, a simulated model of the human autonomy which looks, feel and respond like a real human body is created for the surgeon to operate on. The simulator surgery results can be evaluated before the surgery is carried out on real patient. This helps 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 numbers of times and finalizing the parameters for good surgical results.

The surgeon can also 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.

Fig.2.1 View of Virtual Surgery

Virtual surgery to simulate procedures and train surgeons grew out of the video game industry. Video games for entertainment has been one of the largest industries in the world for some time. However, as early as the 1980s, companies such as Atari began working on ideas of how to use these video environments for training people in different tasks and different professions. Younger trainees in the medical field showed greater eye–hand coordination and quick-thinking abilities over those who had never played. Although graphics were extremely limited, Atari began developing several types of simulators related to health care. This type of training met with strong skepticism until studies in the mid-1980s began to show that the concept had promise.

2.1 HISTORY

The first virtual surgery was performed on 17 August 2009 when Dr. David Clarke in Halifax, Nova Scotia removed a brain tumor 24 hours after removing a simulated tumor.

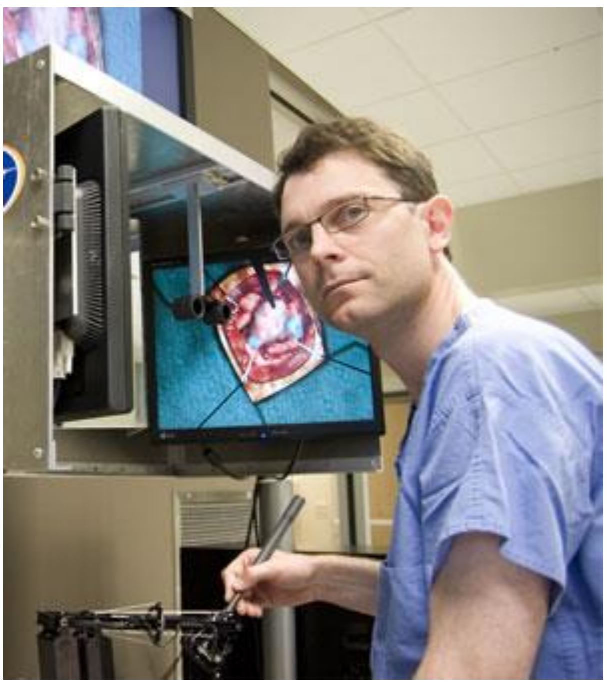

Fig.2.2 Dr. David Clarke during first virtual surgery

A Halifax brain surgeon has removed a brain tumour after using a virtual reality-based simulator, a medical advance considered to be a world first.

A neurosurgical team took pictures of a patient's brain using an MRI at the Queen Elizabeth II Health Sciences Centre.

Neurosurgeon Dr. David Clarke then mapped out the tumour and his surgical approach using a virtual reality neurosurgical simulator, and this week he removed the tumour.

"This means we are able to do a dry run of the surgery to better determine how to remove the tumour safely," Dr. Clarke said in a statement Thursday.

"By practising surgeries in advance of the real thing, we'll be better able to anticipate and fix potential problems before they occur."

The simulator, developed by the National Research Council, will become an important part of neurosurgical training, he added.

The council is preparing to deliver seven prototypes of the simulator to Canadian hospitals over the next two years.

Brain tumour surgery is a high-risk operation because of the potential for damage to surrounding brain tissue and the possibility of tumour recurrence.

3.VIRTUAL SURGERY IN MEDICINE

3. VIRTUAL SURGERY IN MEDICINE

In the last two decades, Augmented Reality has been grown up in the areas of medicine dramatically. Augmented Reality including 3D objects and images equipped by sound and lighting is increasingly being used not only for medical training and education but also in treatment and diagnosis. Professional study on MRI (Magnetic Resonance Imaging), CT(Computed Tomography) scan and X-Ray is one of the highlighted and widely used of virtual reality in medicine. Moreover, awareness on different types of diseases is one other mainly used of virtual reality in medicine.

3.1 MEDICAL IMAGES

Although medical imaging has compiled about the date yet, we can take a look at the role of scientists and engineers in physics and electronic. The first modern imaging techniques and modalities can be referring to the discovery of X-rays by William Roentgen in 1895. More advanced efforts to the radiography imaging systems such as X-ray screens of the resonator, degree course, etc. occurred around 10–20 years later but the main improvements is originated from the laboratory people compare to engineers in physics or electronics. A big revolution on imaging took placed from the 1950s until the end of 1970s. Many new systems for anatomic imaging and the process of the disease were developed in this era. This revolution began with nuclear imaging and ultrasound in spite of the serious limitations on imaging. Computed Tomography (CT) was another invention in medical illustration, which was introduced in the early 1970. By this technique the cross-sectional images came very good, which correspond to the information obtained from the exploratory surgery. Virtual Reality Applications in surgery helps to understand three-dimensional complex structures. Virtual reality applications can be categorized into four types which are training and education, surgical planning, image guidance, and telesurgery.

3.1.1 2D IMAGES

Technique and process used to create images of the human body or its parts and its functions for clinical purposes including medical procedures seeking recognition, treatment, and evaluation are the disease or medical science includes anatomic and physiologic studies is called medical imaging. It is a conflict of several branches of science, such as medical physics, medical, biology, engineering, and optics. 2D images are one of the oldest human inventions in technology century. Various types of 2D images in medical are widely used more than 4 decades. Radiography including projection radiography and fluoroscopy, MultiPlanar Rendering (MPR), Nuclear medicine, Elastography, Tactile imaging, Photoacoustic imaging are some samples of 2D images which are using in medical (Fig. 3.1).

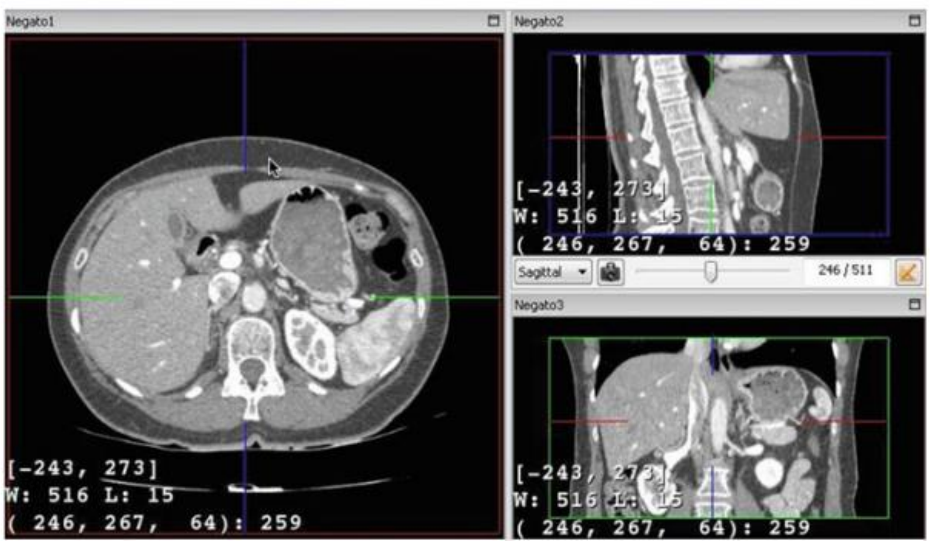

Fig. 3.1 Multi-planar rendering 2D medical image view

3.1.2 3D IMAGES

Tele-surgery allows surgeons to operate on people who are physically separated from themselves. This is usually done through robots provided with video cameras. More advanced system has been used to perform Coronary Anastomosis on ex vivo swine hearts and in human undergoing endoscopic Coronary Artery Bypass grafting. 3D images are the advanced images, which show whole or some parts of body in the dimension. Body imaging can be included of CR Urography and CT Colonography. Cardiovascular Imaging consists of some different parts such as Coronary artery CT angiography, Vascular CT and MR angiography of the aorta, upper and lower extremities, Cardiac MRI and MRA and Pulmonary vein and left atrial imaging for EP planning. Neuroradiology is another part, which includes of CT and MR angiography of the head and neck, MR spectroscopy of the brain and CT and MR brain perfusion. Musculoskeletal Imaging which is 3D reconstructions for preoperative planning. Last but not least is Thoracic Imaging which includes 3D airway reconstructions and Lung nodule volumes. A comparison between 2D and 3D images can be observed in Fig. 3.2.

Fig. 3.2 Musculoskeletal imaging, left 2D X-Ray, right 3D reconstructions for preoperative planning

3.2 3D VIRTUAL BODY STRUCTURES

A 3D virtual body is usually needed to be observed each part of body in any clinic or policlinic. The 3D model cannot reveal all part of body. Thus, a 3D virtual body is more useful to be used for this matter. Through this virtual model the doctor can interact with each part of the 3D model and explore where the problem is. Figure 3.3 (left) illustrates interacting with virtual environments. Figure 3.3 (right) shows an Augmented Realty system in medicine. The virtual skeleton is exerted on real body. Virtual Reality Medical Center (VRMC) in San Diego produced some related application in this area. Pain Management which is a pain distraction application. Combating Phobias using cognitive-behavioral therapy (CBT) in virtual reality to treat patients with several phobias.

Fig. 3.3 Left denotes MIS training system for VR-based simulation of the cholecystectomy surgery scenario, Right denotes virtual skeleton on real body in an augmented reality environment

4. GENERATIONS OF SURGERY

4. GENERATIONS OF SURGERY

Different generations of surgery include

- Early Time
- Refining the appearance
- Adding physiological details

4.1 EARLY TIMES

“Deformable model” is a term that refers to the mid of eighties regarding to the computer imaging. Monserrat et al in 2005 divided the deformable models of existing simulation for surgery into three categories.

Heuristic, hybrid and continuum mechanical were all existing model which belonged to the first generation at that time. All related approach to spring-masses were categorized into the heuristic group. Most of the approaches at that time were included in the continuum mechanics which were based on linear elasticity.

One of the approaches that deserves a special comment is surgical cutting. Continuum-based simulations have been preferred to be used for GPU implementations and X-FEM technique from the time of cutting spring mass systems.

4.2 REFINING THE APPEARANCE

As the Early Times past quickly, some refining needed to be considered such as involving the existing simulators with realistic sensations.

One of the high importance models is Saint Venant-Kirchhoff (SVK) which were not unstable under compression but has been used for many recent works. Point-Associated Finite Field (PAFF) was developed which could approximated the large deformation fields such as surgical tools.

Deo presented a system which is trained with a wide set of possible load states in the case of real-time performance based on neural network for execution loop.

4.3 ADDING PHYSIOLOGICAL DETAILS

The third, fourth and fifth generation aimed to add more and more details. In addition of quantitatively, realizing the simulating physiology of human is a challenging part of virtual surgery since two last decades.

A clear paradigm can be observed in the project of Physio me. On the contrary of physiology in simulation, which was not strictly required, surgical planning was in order.

Guiatni et al developed a new haptic simulation consists of force and thermal feedback which are very useful for the location of tumors. However, physiology in simulation is not avoidable. To predict the outcome of vein graft surgery a physiology in simulation is taken into account.

5. VIRTUAL SURGERY SIMULATION

5. VIRTUAL SURGERY SIMULATION

Virtual surgery is focused around the following simulations

- 3D Simulation
- Touch Simulation

The above simulations comprise and form virtual surgery simulator.

5.1 3D 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 collided 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 per second.

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.

Fig. 5.1 3D generated model of required part of anatomy

5.2 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, lifesaving surgical procedure. So haptics, or the ability to simulate touch, goes a long way to make virtual reality simulators more lifelike.

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 born, etc. it requires a higher update rate than bumping into something a little squishy like skin, liver etc.

But still, simulating squish is no easy task either. The number of collisions 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 sigmoid-scope, 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, prodded, 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 anisotropic, 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.

Fig. 5.2 Phantom Desktop 3D touch screen used in virtual surgery

5.2.1 PHANTOM DESKTOP 3D TOUCH SCREEN

Sens Able technologies, a manufacture of force- feedback interface devices, have 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-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 extent or enhance interactive functionality. The Phantom haptic device has been incorporated into the desktop display by Reachln 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.

6. VIRTUAL SURGERY SIMULATOR

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The VR simulator basically consists of a powerful PC which runs the software and an interface called 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.

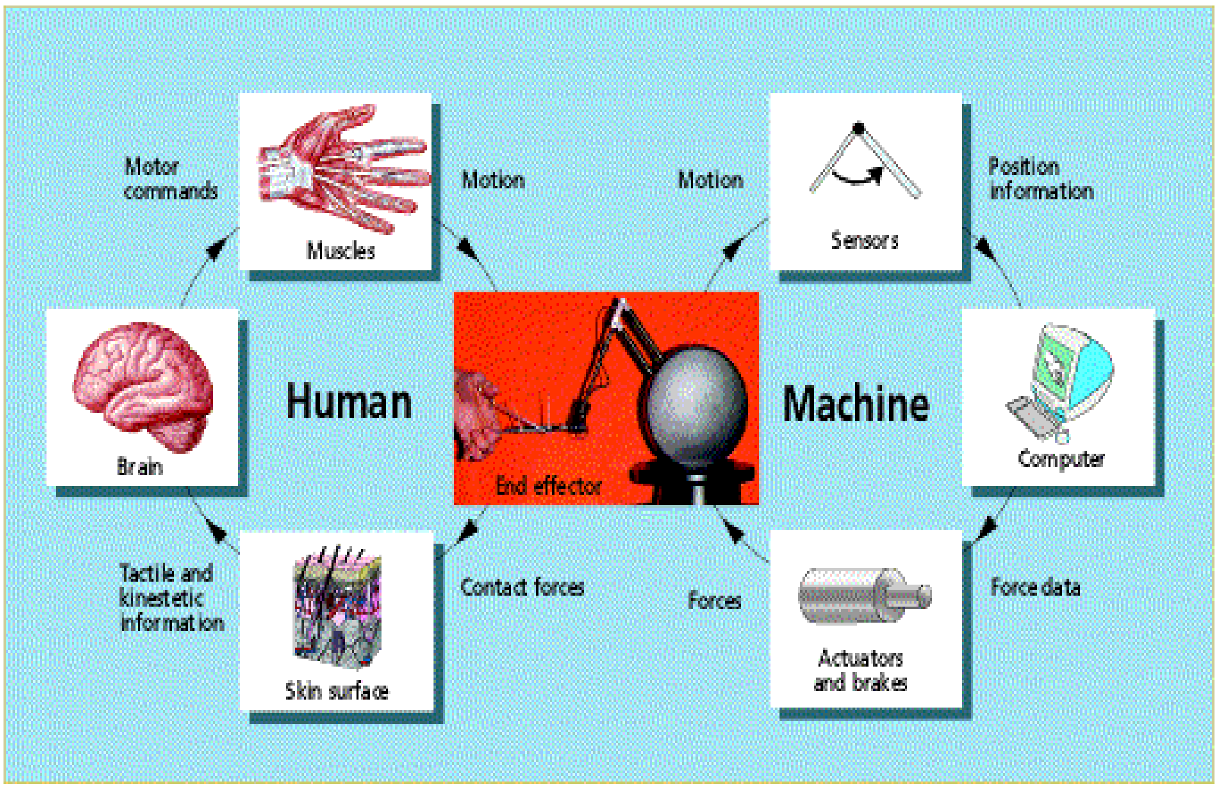

Fig 6.1 Representation of a Haptic feedback loop and how human sense of touch interacting with a VR system. A human hand moves the end effecter-shown here with hemostat-of a haptic device causing the device to relay its position via sensors to a computer running a VR simulation

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 effecter.

In the left hand loop, forces on the end effecter 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 effecter.

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 color 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.

6.1 FEATURES

- CE certified (Chartered Engineers certification)
- Portable design and compact footprint for workplace
- flexibility
- Wrist rest to maximize user comfort
- Multi-function indicator light
- Compact workspace for ease-of-use
- Constructed of metal components and injection moulded, carbon fibre reinforced plastics
- Automatic workspace calibration

6.2 STRUCTURE OF VIRTUAL SURGERY SIMULATOR

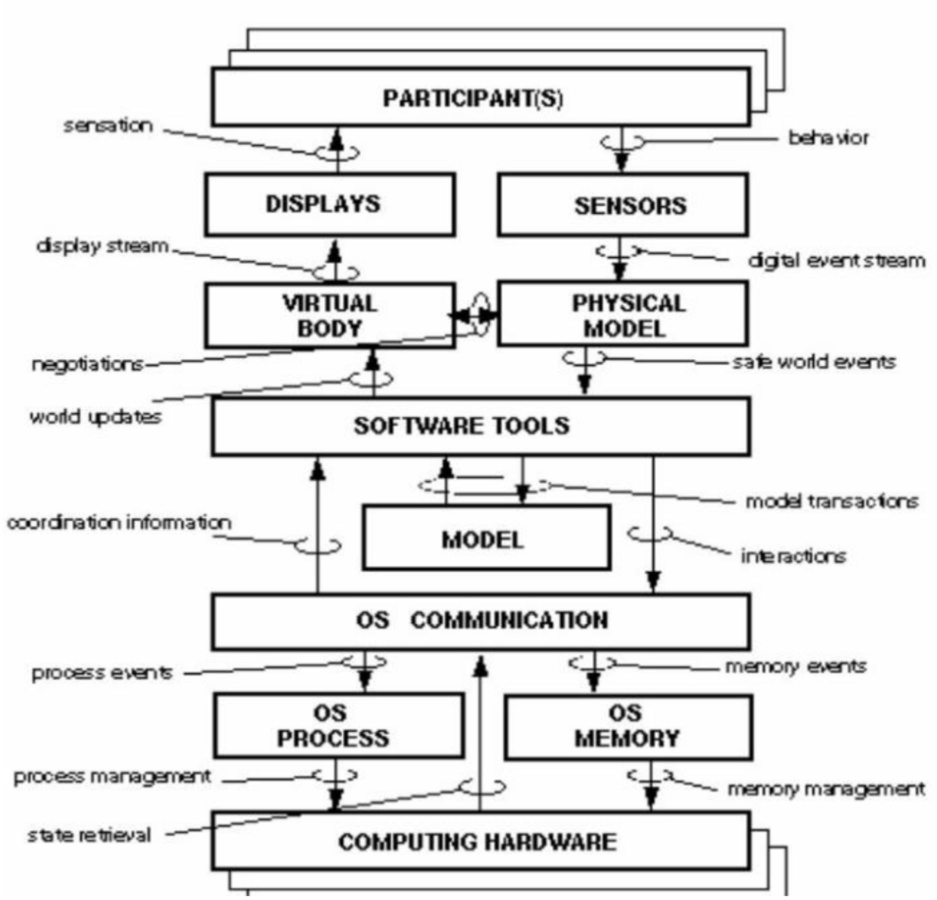

Fig.6.2 Structure of Virtual Surgery

The behaviour and sensory transducing subsystem (labelled participant, sensors and display) converts natural behaviour into digital information and digital information into physical consequence.

The virtual toolkit subsystem (the physical model, virtual body, software tools and model) coordinates display and computational hardware, software functions and resources, and world models.

The computational subsystem (the operating system and hardware) customizes the VR software to a particular machine architecture. Presence is the impression of being within the virtual environment.

The development of patient-specific digital models provided a foundation for procedure simulation, and ongoing studies of approaches to adapt these models so that they accurately present conditions during a specific intervention. The two primary goals of VR (or "immersive") simulators are 1) to enable training in a realistic and consistent environment, and 2) to rehearse an actual procedure, so that the physician does not "practice on the patient." Real time adapted models were focused on providing augmented reality data support intraprocedural.

In 1992, the surgeon was surrounded by opportunity. We were at the peak of a golden age of medical imaging technology established by CT, MRI, and the ongoing conversion to digital image data; the following decade would see an explosion of advanced systems and concepts in several modalities, and a wide range of new diagnostic instruments and approaches. This was matched by comparable potential in telemedicine, robotics, surgical simulation, and minimally invasive surgery:

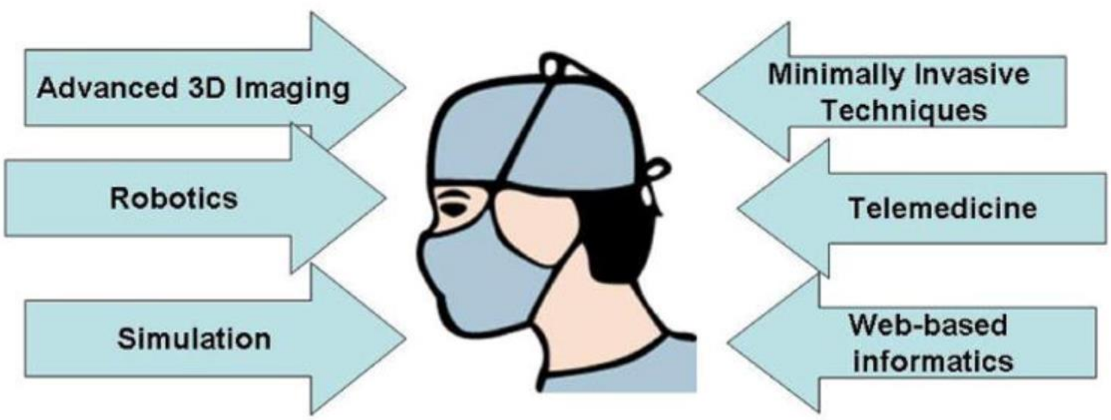

Fig.6.3 Virtual surgery providing comparable potential in telemedicine, robotics, surgical simulation, and minimally invasive surgery

7. SURGICAL SIMULATOR REQUIREMENTS

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Surgical simulator requirements include:

7.1 DATA ACQUISITION

Data collection is the first step to create a realistic model of the organ. An accurate data is required to be able to show the organ like what can be seen and interacted with real one.

In Virtual Reality systems usually, a realistic model is needed to be replaced by the real organ. The reaction and movement of the model must be the real one. This requires an accurate date.

7.2 IMAGING MODALITIES

The integration of advanced imaging technology, image processing and 3D graphical capabilities has led to great interest in image guided and computer aided surgery.

Navigation in surgery relates on stereotactic principles, based on the ability to locate a given point using geometric reference. It also proved useful in Robotic Surgery, a new technique in which surgeon remotely manipulate robotic tool inside the patient body.

Variety types of organs need different type of data. Most of the organ issues can be diagnose using different imaging modalities. Currently, there are some image modalities which the main ones are as follows.

CT: CT or Computer Tomography usually gives a fast and obvious diagnosis of many different conditions.

PET/CT: PET/CT is an integration of PET (Positron Emission Tomography) and CT which gives images illustrating active pathology and anatomical location of astonishing.

MRI: MRI or Magnetic Resonance Imaging which is a magnetic resonance imaging. It is based on magnetic resonance core. Currently MRI is widely used in medical and veterinary diagnostic.

Cardiac MRI: Cardiac MRI creates both still and moving pictures of your heart and major blood vessels. The preferred investigation choice for many clinical indications and applicable for cardiovascular system. Different types of heart diseases can be diagnosed by Cardiac MRI like: Coronary heart disease, Heart failure, Damage caused by a heart attack, Heart valve problems, Cardiac tumors, Congenital heart defects and Pericarditis.

X-ray: X-ray is one of the oldest images in medical. It creates a picture of the inside of the body focusing on the bones.

Ultrasound: This method is based on ultrasound for subcutaneous tissues such as muscles, joints, tendons and the internal organs of the body. There is also a widely used of ultrasound in pregnancy.

Obstetric and maternal fetal ultrasound: This technology allows observing real-time 3D and 4D views of bone densitometry or DEXA.

Fluoroscopy: Fluoroscopy is a technology that creates a real-time moving image using X-ray and reduces the patient's radiation dose. This technology allows to scan all areas of the body in all directions. Currently, Fluoroscopy is used in conjunction with MRI for MR Arthrography.

7.3 SEGMENTATION

Segmentation is extracting and characterizing features of available data which are obtained from patient. There are some different types of segmentation and they have been classified as structural and statistical methods. Fast and accurate segmentation are more important to create VR-based intra-operative surgery.

7.4 FUSION OF MULTI-MODALITY DATA

Fusion of different types of data is another part of some surgical simulators.

By fusing and registering multi-modal images multidimensional properties of human organs cab be created.

7.5 REGISTRATION

A common reference frame process between pre-surgical data and the corresponding patient anatomy is called Registration. This pre-surgical data can be used in intra-operative when the reference frame is established. Thus, the presurgical data can visualize the anatomical structures not only for intraoperative data but also for many other purposes such as surgical equipment, guide a surgeon's tool movements, position radio and guide robotic tool movements.

7.6 MODELING

One of the main steps regarding to have a realistic VR-based application in surgery is realistic modeling. There are two different methods to creating the model. The first one is modeling based on current data from existing images like MRI, CT, and PET. As this method reconstruct the model based on the real data it is accurate enough, but it is different from different patients. The second one is modeling using handcraft modeling tools.

Kaye et al presented a mechanical cardiopulmonary which is interactive in 3D virtual environments. Sorensen et al developed a realistic model of cardiovascular which is interactive to be used for training of virtual surgery. The purpose of this simulator was not only illustration of various elements of heart surgery but also allowing surgeons to rehearse difficulty of open-heart surgery before any cardiovascular surgery.

The morphologically model is reconstructed based on from 3D MRI data. Reconstruction of the morphology for any patient is employed based on a post-processing invent. In preoperative planning process, an accurate reconstruction of intra and extra-cardiac morphology can be integrated while computer visualization hardware allows interactive elastic tissue deformations simulation. Different surgical strategies can be evaluated preoperatively by visualizing the morphology in respect for each incision.

7.7 INTERACTION

There are many different data which can be extracted from the patients. Variety of data in VR systems needs and interactive application to be navigated by users or surgeons. Collision detection and position tracking are the concepts that are in order to be employed in many of the surgical applications. Interacting with different parts of body or even different parts of a system like cardiovascular system needs tracking technique to be navigated by surgeons through some many devices like optical, mechanical, magnetic, and acoustic (Fig 7.1).

Fig. 7.1 Two Phantom Omnis (Sensable Technologies, USA) allow cutting and tissue manipulation can be done interactively with it's free-hand interaction that also give force feedback

8. APPLICATIONS

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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:

8.1 TRAINING AND EDUCATION

Training and education simulators have their own strategies and protocols. Level of difficulty and psycho-motor skills are the main parameters which are taken into consideration. A VR-based application is useful due to avoiding any dangers from the patients. Training applications usually have an elevation part for any step of training. However, the main challenge is to produce a step with adequate fidelity to be simulated like what is performing on the patients.

The other ability of training and education simulators is preparing a situation for research surgeons to simply practice what has been suggested by other colleagues and even reading form websites. In other word, development of innovative for surgical instruments can be employed using training and education simulators easily.

For a more realistic and natural surgical training scenario, the position of the thorax should be addressed. Young surgeons are allowed to do numerous amounts of surgical training scenario with limitless trial so that they can learn more from their mistakes. The time for the training could become shorter and thus the cost will become lesser. For this project, to evaluate potential corrective strategies for patients' three-dimensional magnetic resonance imaging (3D MRI), incision simulation has been performed.

Traditionally, textbook images or cadavers were used for training purposes. 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.

Piromchai has reviewed the virtual reality surgical training in ear, nose and throat surgery. The details include temporal bone dissection surgery, middle ear surgery for myringotomy, Benign Paroxysmal Positional Vertigo (BPPV) surgery, cochlear implantation, Endoscopic sinus surgery, phonosurgery, laryngeal surgery, cricothyroidotomy, and bronchoscopic surgery.

Fig. 8.1 Virtual surgery in training and education

Computer-based training has many potential advantages:

1) It is interactive.

2) An instructor presence is not necessary, so student' can practice in their free moment.

3) Changes can be made that demonstrate variation in anatomy or disease state.

4) Simulated position and forces can be recorded to compare with established performance matrices for assessment and credentialing.

5) Students could also try different technique and loot at tissues from perspective that would be impossible during real operations.

8.2 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 stereo-static 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.

8.3 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 inter-operative surgical navigation is referred to as Computer Aided Surgery.

Navigation in surgery relates on stereo-static 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.

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 within reasonable time frame.

Fig.8.2 Image guidance provided by virtual surgery

8.4 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. More advanced system has been used to perform Coronary Anastomosis on exvivo swine hearts and in human undergoing endoscopic Coronary Artery Bypass grafting.

8.5 INTRA OPERATING

Accurate localization of the place of many different types of surgery on the tissue is needed for adjacent the structures. Doing a test on the exact location is most of the time impossible or difficult to do especially when the structure under treatment is deep.

In these cases, Intra-Operative Assistance is more helpful and can be transferred to the operating rooms. Augmented Reality is more suitable for these types of pre-operative surgical to guide surgeon using the pre-operative data for intra-operative data.

8.6 ASSISTANCE SURGERY TOOLS

Currently, Image-guided surgery and robotically assisted surgery are the main tools in surgery rooms. Image-guided has been used for many years while robotically assisted surgery has been sued for some decades. Surgeons can use VR-based systems with visual access of the location into the location of the tissue. Through the assistance surgery tool, the surgeons can access many parts of patient inside. Collaboration and telemedicine are some of the extensions of this tools which can be used to remove the distance between surgeons and make it easy to communicate and sharing the information for whole around the world.

To give a 3D overview of the morphology process, virtual reconstructions were introduced as a new supplementary tool to assist the process. By using two Phantom Omnis by Sensible Technologies, two-handed interaction was achieved which providing the exact position and orientation of the 3D hands. To provide a natural sensation, the devices have been programmed to give feedback force when the 3D hands touching the reconstructed 3D virtual heart which allow the user to feel the magnitude of the forces applied during the simulation.

8.7 TOUCH SIMULATION

A haptic-touch sensation is simulated. Physicians rely a great deal on their sense of touch for everything from routine diagnosis to complex, life-saving surgical procedure. A low update rate is needed for soft tissues whereas hard tissues require high update rate. For simulating touch sensation, we have to calculate the forces applied to cut, puncture the various tissues.

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 and the reaction forces are also calculated. 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 30 Hz.

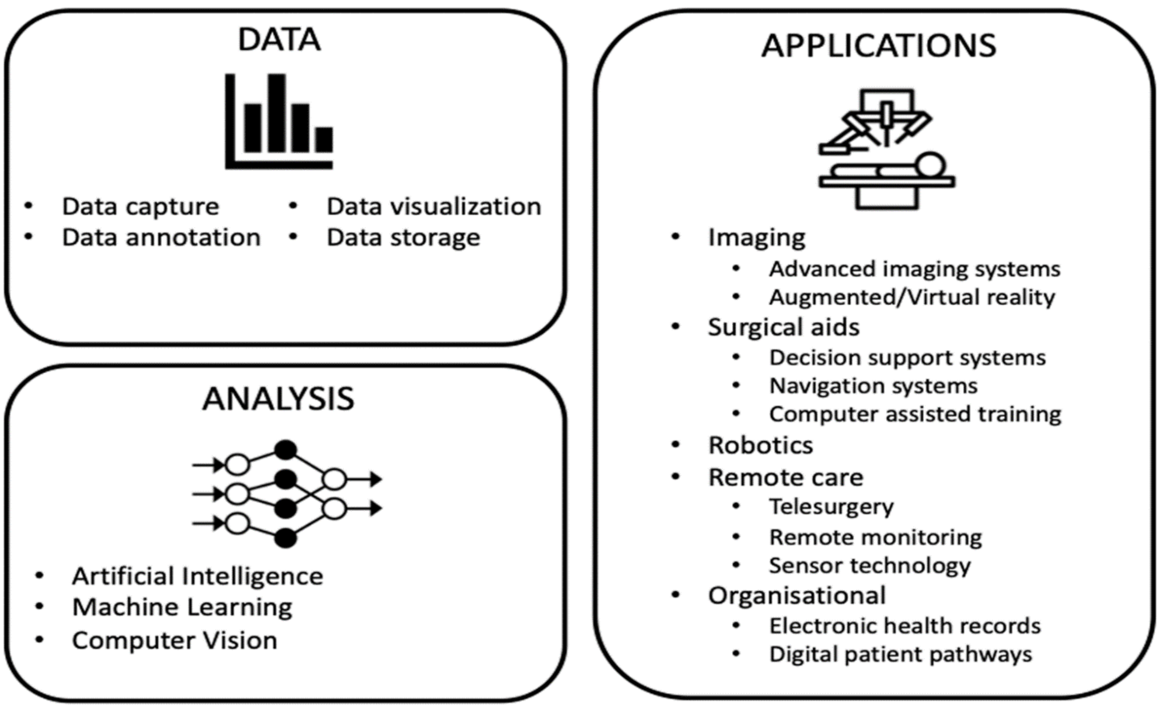

Fig.8.3 A Delphi consensus statement for digital surgery

8.8 CASES THAT INVOLVED VIRTUAL SURGERY


BUSINESS INSIDER
INDIA

Surgeons use virtual reality to separate twins with conjoined heads in a 27-hour-long surgery

RAHUL VERMA | AUG 3, 2022, 11:02 IST

Fig.8.4 Newspaper article stating that involvement of virtual surgery of cojoined heads


NewScientist

Virtual syringe lets surgeons practise piercing skin and muscle

TECHNOLOGY 13 April 2017

Fig.8.4 Newspaper article stating that involvement of virtual surgery of Knee

9. ADVANTAGES

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A recent report released by Institute of Medicine in Washington DC, estimates that medical errors effects in about 100,000 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.

The virtual model of surgery in preoperative planning provides:

- further diagnostics, objective model measurement data,
- simulation of the procedure and matching the optimal surgical method for the case and the possibility to predict the final outcome,
- possibility to choose/create an optimal implant, matching the anatomy of the patient,
- possibility to design surgical guides for correct guidance of the surgical tools during the procedure,
- the verification of the planned surgery due to analysis using, among others, computational physics methods.

10. CHALLENGES

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Apart from a number of benefits, doctors indicate some problems involved in preoperative Virtual surgical planning, too:

- Cost and processing power of available hardware.
- Need to improve human-computer interfaces.
- Time delays in the simulator's response to the users' movements.
- Time-consuming process of creating virtual 3D models, especially in case of soft tissues,
- Necessity to perform high-resolution tests in order to receive high precision effect (the applied tests refer to distance between the planes of no longer than 1mm).
- Necessity to spend time for preoperative planning.

11. CONCLUSION

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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.

12. REFERENCES

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1. Daniel Sorid & Samuel K. Moore “The Virtual Surgeon”, IEEE Spectrum

2. Paul J Gorman, MD; Andreas H Meler, MD; Thomas M Krummel, MD, “Simulation and Virtual Reality in Surgical Education Real or Unreal ?“, Archives of Surgery

3. R Satava “The King is Dead” Medicine.

4. Mandayam Srinivasan; CagatayBasdogan, “Haptics in Virtual Environments: Taxonomy, Research Status and Challenges”, Computers and Graphics, vol 21, no4, pp.

5. SensAble Devices,Inc., “The PHANTOM’, literature from SensAble Devices Inc.