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DEVENDRA NAGAL
Department of Electrical Engineering, MBM Engineering College, JNV University, Jodhpur, India,
devendra.nagal@gmail.com

S. S. MEHTA
Department of Electrical Engineering, MBM Engineering College, JNV University, Jodhpur, India,
ssmehta_58@rediffmail.com

SWATI SHARMA
Department of Electrical Engineering, MBM Engineering College, JNV University, Jodhpur, India,
er.swati.sharma15@gmail.com

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VIRTUAL REALITY IN BIOMEDICAL

DEVENDRA NAGAL[1], **S. S. MEHTA**[2] **& SWATI SHARMA**[3]

[1,2&3]Department of Electrical Engineering, MBM Engineering College, JNV University, Jodhpur, India
Email: devendra.nagal@gmail.com, ssmehta_58@rediffmail.com, er.swati.sharma15@gmail.com

Abstract— Virtual reality (VR) encompasses a number of surgical research topics, including computer graphics, imaging, visualization, simulation, data fusion and telemedicine. In this paper we define virtual reality and each of these areas, focusing on a state-of-the-art review of the research and recent accomplishments. .Virtual reality is a powerful technology for solving today's real-world problems. Virtual reality refers to computer-generated, interactive, three-dimensional (3-D) environments into which patients are immersed. It provides a way for surgeon to visualize, manipulate and interact with simulated environments through the use of computers and extremely complex data.

Keywords- *Virtual reality, DataGlove, Endovascular Evaluator.*

I. INTRODUCTION

Virtual reality is the use of a computer interface to simulate, in a synthetic environment, a real or imaginary world, through the computer operator's senses. These are most commonly visual, tactile (haptic), or auditory senses and allow for an interactive, virtual environment. The terms *virtual reality*, *synthetic environment* and *virtual environment* are often used interchangeably. The historic ancestors of virtual reality are the flight simulator and the popular videogames.

A review of the literature shows that small group discussions, interactive videos and simulated patient encounters have been employed. Virtual reality is playing a critical role in credentialing surgeons. With its power to allow training and testing in any procedure, it serves as an objective tool to measure competence, just as it is used in the airline industry. It offers the additional advantage of avoiding the use of animal models or patients to improve surgical skills. Virtual reality for teaching and credentialing is an important area for further research. In the following discussions we explore three-dimensional (3D), multidimensional and multiuser virtual human modeling applications. We then look to virtual environment representation. The use of virtual tools and manipulation in surgical simulators will also be reviewed. The use of augmented reality to benefit surgical planning and procedures and the roles that telesurgery and cybersurgery may play in the coming years are then examined.

VR-based telepresence systems are used in surgery to manipulate equipment at remote sites. Its advantages are clear. For instance, a specialist can help a local surgeon by remote connection, or surgeon to perform complex operations where the local provider is in a rural setting, a ship at sea, an airplane in flight, or even a space station. Besides solving the distance problem, telepresence offers other benefits, such as minimizing the exposure of surgeons to infections

II. OVERVIEW OF VIRTUAL REALITY TECHNOLOGY

The term "Virtual Reality" describes the experience of interacting with data from within the computer-generated data set. The computer-generated data set may be completely synthetic or remotely sensed, such as X-ray, MRI, PET, etc images. Interaction with the data is natural and intuitive and occurs from a first-person perspective. From a system perspective, virtual reality technology can be segmented as shown in Figure 1.

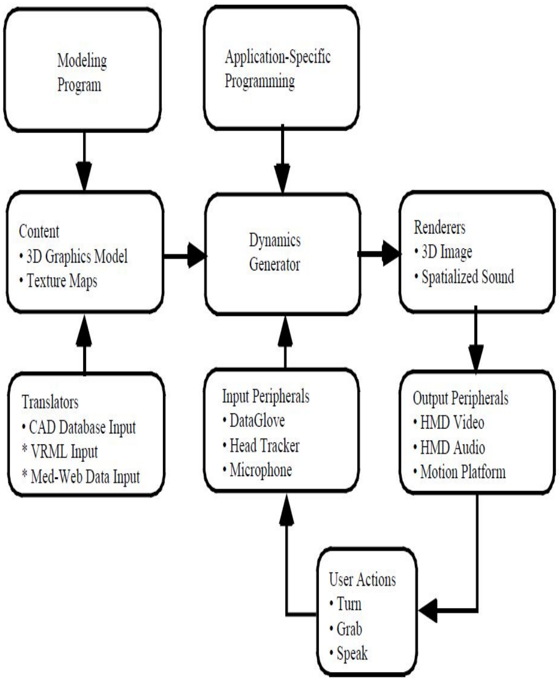


Fig.1. A complete Virtual Reality system.

The computer-generated environment, or virtual world content, consists of a 3D graphic model, typically implemented as a spatially-organized, object-oriented database; each object in the database represents an object in the virtual world. A separate modeling program is used to create the individual objects for the virtual world. For greater realism, texture maps are used to create visual surface detail.

The data set is manipulated using a real-time dynamics generator that allows objects to be moved within the world according to natural laws such as gravity and inertia, or to other variables such as spring-rate and flexibility that are specified for each particular experience by application-specific programming. The dynamics generator also tracks the position and orientation of the user's head and hand using input peripherals such as a head tracker and DataGlove.

Powerful renderers are applied to present 3D images and 3D spatialized sound in realtime to the observer. The common method of working with a computer (the mouse/keyboard/monitor paradigm), based as it is on a two-dimensional desk-top metaphor, is inappropriate for the multi-dimensional virtual world. Therefore, one long-term challenge for Virtual Reality developers has been to replace the conventional computer interface with one that is more natural, intuitive and allows the computer not the user to carry a greater proportion of the interface burden.

Instrumented Clothing

The DataGlove™ and DataSuit™ use dramatic new methods to measure human motion dynamically in real time. The clothing is instrumented with sensors that track the full range of motion of specific activities of the surgeon wearing the Glove or Suit, for example as the wearer bends, moves, grasps or waves. The DataGlove as shown in figure 2 is a thin lycra glove with bend-sensors running along its dorsal surface. When the joints of the hand bend, the sensors bend and the angular movement is recorded by the sensors.

These recordings are digitized and forwarded to the computer, which calculates the angle at which each joint is bent. On screen, an image of the hand moves in real time, reflecting the movements of the hand in the DataGlove and immediately replicating even the most subtle actions. The DataGlove is often used in conjunction with an absolute position and orientation sensor that allows the computer to determine the three-space coordinates, as well as the orientation of the hand and fingers. The DataGlove is often used in conjunction with an absolute position and orientation sensor that allows the computer to determine the three-space coordinates, as well as the orientation of the hand and fingers.

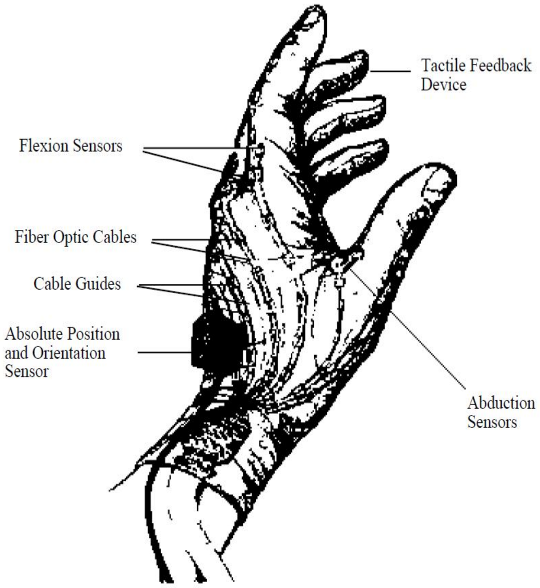


Fig.2. DataGlove

III. SIMULATING VASCULAR DISEASES TREATMENT

The result of 20 years of joint research between engineers and physicians, the Endovascular Evaluator (EVE) as shown in figure 3 is a tailor made model of human vascular lumen, created with a patented modeling technology using CT/MRI Data. High precision models of the principal vascular structures (Cerebral-Coronary-Hepatic-Renal) were integrated to create EVE. EVE provides a realistic IVR environment simulation experience that will satisfy our necessities for medical training, medical tools evaluation and surgery rehearsal.

Medical Treatments supported by EVE

- Cerebral Artery Embolism with coil or balloon.
- Percutaneous Transluminal Angioplasty (PTA) with a balloon or stents.
- Percutaneous Transluminal Coronary Angioplasty (PTCA)
- Carotid Artery Stenting (CAS)
- Transcatheter Hepatic Artery Embolization (THAE)
- Percutaneous Transluminal Recanalization (PTR)
- Catheter and Guide Wire Insertion Aortic Stents Grafts

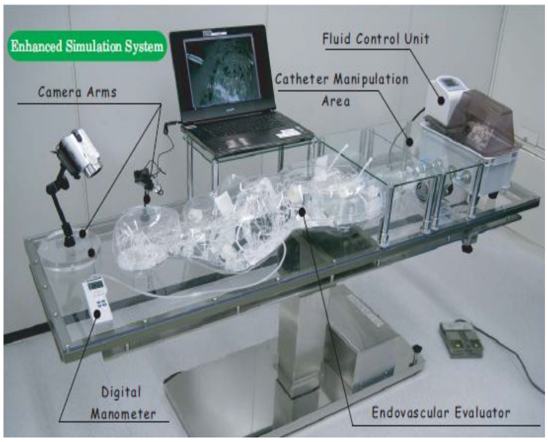
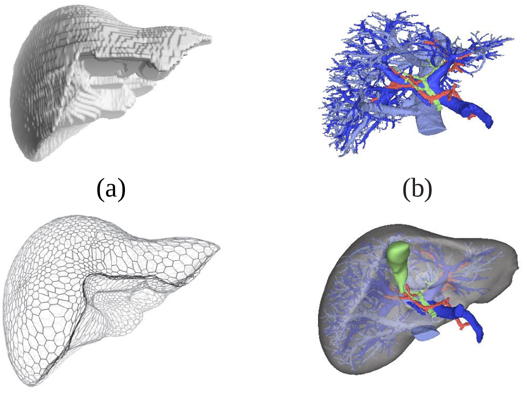


Fig.3. Endovascular Evaluator

IV. GEOMETRICAL MODELLING

In order to create a very realistic model for example of the liver, we use the images of the Visible man. These images are high resolution (1 mm) colour pictures of cryogenic cross-sections of a cadaver. The digital image processing tools of the Epidaure group is used to extract the external boundary of the liver, and also the various vessels (veina cava, portal vein, hepatic artery, billiary duct). Then a volumetric representation is created.



(a) (b)

(c) (d)

Fig.4. (a) Liver model built from a set of 2D segmented medical images, (b) result of the vascular tree segmentation. (c) Surface mesh of the liver. (d) Anatomical liver model.

Finally, an isosurface extraction provides the mesh of a 3-D surface corresponding to each structure (figure 4). One obtains a set of 5 surface meshes, either triangulated or with a *simplex mesh*. These surfaces can be manipulated interactively through a graphical interface. The surgeon can therefore plan surgery with the accurate knowledge of vessels location with respect to the liver external boundary, which is the only visible item during the actual surgery. With the use of this 3D reconstruction, it is possible to visualize with transparency the different vessels of the liver, and therefore to plan the impact of each medical gesture. Doing this can reduce drastically the risk of cutting a major vein or artery during surgery.

V. OVERVIEW OF VIRTUAL REALITY IN MEDICINE

The use of virtual reality in medical applications provides for better image manipulation, improved image understanding, improved quantitative comparisons and better surgical planning. Healthcare's potential use of interactive 3D technologies is broad. To date, most of the media's attention has centered on two application areas: surgical training and planning and computer-aided surgery systems. However, the possible uses are much broader. The following categories in table shown below represent current and emerging applications of VR in medicine:

Application	*Description*
Medical / Dental Surgical Training	Training and rehearsing a surgical procedure using surgical instruments linked to a realistic simulation – may or may not include haptic feedback.
Pre-Surgical Planning	Using 3D radiological images and computer workstation tools to design and plan an operative procedure.
Computer-Aided Surgery Systems	Using 3D images overlaid in real-time on the operating field to facilitate surgery.
Interactive 3D Diagnostic Imaging	Tools for data analysis and quantitative comparisons capturing and manipulating medical imaging data in a 3D format. Collaborative environments.
Medical Education	Case histories, 3D anatomy lessons and virtual cadavers, procedure training, ER ward simulation, palpation training, etc.
3D Visualization for Telemedicine	Radiological image tele-consultation and second opinions, shared data for tumor review boards, remote patient examination and specialty consults.
Telesurgery	Computer-assisted surgery at a distance. Predictive algorithms, 3D surgical planning.
Rehabilitation and Sports Medicine	Simulated environments for evaluation and rehabilitation occupational therapy, physical therapy, ergonomics, orthopedics and sports medicine.
Disability Solutions	Augmented Reality environments for treatment of autism and other cognitive impairments. Environmental control systems.
Neurological	Standardized simulated

Evaluation	environments for evaluation of cognitive processing, stroke deficits, memory disorders, movement disorders and higher-functions.
Radiation Treatment Planning and Control	Design of radiation treatment procedure to match patients' anatomy precisely. 3D design and control systems.

VI. VIRTUAL REALITY APPLICATION EXAMPLE

Virtual reality had been researched for years in government laboratories and universities, but because of the enormous computing power demands and associated high costs, applications had been slow to migrate from the research world to other areas. Continual improvements in the price/performance ratio of graphic computer systems, however, have made VR technology more affordable hence used more commonly in a wider range of application areas Applications today are diverse and represent dramatic improvements over conventional visualization and planning techniques:

1) **Public Entertainment:** VR made its first major inroads in the area of public entertainment, with ventures ranging from shopping mall game simulators to low-cost virtual reality games for the home. Major growth continues in home VR systems, partially as a result of 3D games on the Internet.

2) **Computer-Aided Design:** Using VR to create "virtual prototypes" in software allows engineers to test potential products in the design phase, even collaboratively over computer networks, without investing time or money for conventional hard models. All of the major automobile manufacturers and many aircraft manufacturers rely heavily on virtual prototyping.

3) **Military:** With VR, the military's solitary cab-based systems have evolved to extensive networked simulations involving a variety of equipment and situations. All levels of the military now have the ability to practice as teams in a verity of complex simulation scenarios, practicing search and rescue missions, for example, using acquired details from target-areas modeled into virtual worlds.

4) **Architecture/Construction:** VR allows architects and engineers and their clients to "walk through" structural blueprints. Designs may be understood more clearly by clients who often have difficulty comprehending them even with conventional cardboard models.

5) **Data Visualization:** By allowing navigation through an abstract "world" of data, VR helps users rapidly visualize relationships within complex, multi-dimensional data structures. This is particularly important in financial-market data, where VR supports faster decision making.

VII. LIMITATIONS OF VR

Several current virtual environment applications in health care have problems that limit their effectiveness. Specifically, at least three technical problems limit their actual application. These are as follows:

- ***Cost:*** Although some attempts have been made to use PC-based virtual reality systems, most of the existing VE's are based on RISC platforms whose cost is beyond the reach of the average therapist.

- ***Lack of reference standards:*** Almost all applications in this sector can be considered "one-off" creations tied to a proprietary hardware and software, which have been tuned by a process of trial and error. This makes them difficult to use in contexts other than those in which they were developed.

- ***Non-interoperability of system:*** Although it is theoretically possible to use a single virtual reality system for many different applications, none of the existing systems can be easily adapted to different tasks. This means that two different departments within the same organization may find themselves having to use two different VR systems because of the difficulty of adapting one single system to their different needs.

VIII. CONCLUSION

Virtual Reality (VR) can be considered as the leading edge of a general evolution of present communication interfaces involving the television, computer and telephone. The development of methods of electronic communication, clinicians have been using information and communication technologies for the exchange of health-related information. However, the emergence of new shared media, such as the Internet and virtual reality are changing the ways in which people relate, communicate and live. The offered information technologies, the multimodal man-machine interface and a virtual reality technique find more and more wide applications not only in medicine, but also in other areas (service, home assistance, telecommunications, space, etc.). Thus the intelligence of virtual reality and multi-agent technologies will play especially important role. To spread the use of VR in telemedicine, further research is required. Professionals in this field must share information about their experiences in order to expedite suitable development work in this field.

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