Virtual Reality In Medical Education And Assessment

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ABSTRACT

The NASA Johnson Space Center (JSC)/*Lin*Com Corporation, the University of Texas Medical Branch at Galveston (UTMB), and the Galveston Independent School District (GISD) have teamed up to develop a VIrtual Visual Environment Display (VIVED) that provides a unique educational experience using Virtual Reality (VR) technologies. The VIVED end product will be a self-contained educational experience allowing students a new method of learning as they interact with the subject matter through VR. This type of interface is intuitive and utilizes spatial and psychomotor abilities which are now constrained or reduced by the current 2 dimensional (2D) terminals and keyboards (2). The perpetual challenge to educators remains the identification and development of methodologies which conform the learners abilities and preferences. The unique aspects of VR provide us with an opportunity to explore a new educational experience.

Endowing medical students with an understanding of the human body poses some difficult challenges. One of the most difficult is to convey the three dimensional (3D) nature of anatomical structures. The ideal environment for addressing this problem would be one that allows students to become small enough to enter the body and travel through it - much like a person walks through a building. By using VR technology, this effect can be achieved; when VR is combined with multi-media technologies, the effect can be spectacular.

INTRODUCTION

Medical students, interns, residents and physicians spend a significant amount of their time identifying and organizing data and information based on their educational programs or interactions with patients. It is important that they effectively organize this data and identify any issues that they need to learn about. Many of these "learning issues" can be accessed through the computer. The use of computers to process medical information, known as "Medical Informatics," is becoming more frequently used. This technology has advanced to 3D renderings of human anatomy on a 2D computer screen. Even with this technology and other classic methods, such as dissection of cadavers, there are times when it would be helpful for the user to be able to place himself into the anatomical environment to better understand the true 3D relationships that exist in that particular region of the body. This leads to the need for VR experiences in anatomical imaging. Studying images on a 2D computer screen can be compared to looking at fish through a glass bottom boat (1, 3), whereas VR allows one to put on the scuba equipment and enter the water, interacting with the surroundings without getting wet. This type of learning experience would be an excellent addition to the currently available methods.

With inevitable improvements in imaging for VR and in digital gloves, it is not difficult to visualize future applications for this technology. The practice of general medicine can be compared to activities of an airline pilot, whereby each deals with many routine landings and takeoffs, both also have to be prepared for emergency situations. We have the means to simulate the environment for the pilot allowing him to develop specific skills in routine and emergency situations. Imagine a physician putting on a VR helmet and digital gloves for a clinical

simulation. When the computer is activated, the physician sees the operating room, equipment, staff and patient. He/she holds out a hand, feels a scalpel being placed in it and begins a surgical procedure allowing him to practice the procedure and evaluate any possible problems before opening up the patient.

Fidelity of the images produced is of utmost importance when applied to medical education. Magnetic Resonance Imaging (MRI), Computerized Axial Tomography (CT) scans and <1 millimeter cadaver sections all provide acceptable levels of image quality. The National Library of Medicine is using these methods of data acquisition to build a nationally accessible database of information on human anatomy. This project, know as the Visible Human Project, will provide an invaluable source of data for VR work in medical education.

NASA JSC has used VR to expand its training capabilities. Specifically, by providing a means to incorporate extravehicular activities (EVA) with remote manipulator system (RMS) task training. This same VR technology is being transferred by way of the VIVED project for use in medical education. This is the subject of this paper.

BACKGROUND

In 1990, Dr. Andrew F. Payer was invited to experience a VR prototype for astronaut training that utilized wire frame models of the shuttle and space station. He was placed in the VR module and allowed to translate around objects under his own control. After the experience, he was asked if he thought there were any possible applications to medical education. This was the beginning of an exciting project called the VIrtual Visual Environment Display (VIVED) project.

Discussions with potential commercialization partners identified the need for the project to have applications broader than just the medical school environment (there are only 137 medical schools in the US). It was decided that a joint plan be identified that would allow the VR prototypes to be tested for effectiveness in educational arenas including elementary schools high schools colleges and professional schools. Thus a Memorandum of Understanding was developed between NASA JSC, UTMB, and GISD so that prototypes could be tested in a variety of educational environments.

The human skull was chosen as an initial specimen due to readily available methodology, namely CT scans, of obtaining imaging data for bony structures. A second model of a heart specimen was created using MRI data.

Early models generated for VR did not meet the quality requirements of the project. After using newer CT scanners of higher resolution, and improvements in VR software, the skull image now nears the quality of an actual human skull. Because of the amount of image data, interactive fly-throughs into the skull are not currently possible. However, prescribed fly-throughs are being generated in digital and video formats to utilize mutlimedia technology.

The short term goal of VIVED is to integrate prescribed fly-throughs of the skull with other interactive multi-media (audio, video, etc.) capabilities.

METHODS: CREATING STEREO SEQUENCES OF THE HUMAN SKULL

File Conversion and Data Preparation

Scans of a human skull were performed resulting in a data set consisting of over 120 slices through the skull and 60 slices through the mandible (jaw). The first attempts used 2.5 mm slice thickness and a low resolution scanner resulting in poor image quality. The last scan used a newer high resolution scanner and a slice thickness of 1.5 mm improving the quality tremendously (see Figures 1 and 2).

The data files obtained from the scan were transferred to JSC IGOAL (Integrated Graphics, Operations, and Analysis Laboratory) for further processing. The skull was held in place during the CT scan by a foam band thus creating extraneous data. The scans were then cropped to eliminate as much extraneous data as possible without losing any critical information. The final stage of data file preparation required using a tool developed in the IGOAL called "ctimager" to remove unwanted noise and extraneous data from each slice.

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Figure 1 First Skull attempts using CT data

Figure 2 Current 3D Skull Model

A MRI scan of a human heart was performed resulting in a data set consisting of 200 slices. In order to use the image tools developed to process the skull data, the data for the heart was converted to the same format as the skull data. Ctimager was then modified to automatically remove the noise from each scan.

Data Filtering And Conversion Of Volume Data To Polygonal Data

A tool called "dispfly" was developed in the IGOAL to convert volume data into a form that could be displayed directly by the computer. Dispfly used multiple filtering algorithms to prepare the CT and MRI data for conversion to polygonal form. Anatomical models are generated based on the marching cubes algorithm developed by W. E. Lorensen and H. E. Cline. This technique generates surfaces based on the density of the imaging data. It generates a polygonal surface based on a "logical" cube created from eight data points on two adjacent slices of data. The algorithm determines how the surface of a selected density intersects this cube. A table lookup is performed to determine which triangles describe the surface. The normals are then determined using gradients computed directly from volume data.

The raw data set contains noise from the CT or MRI scanning process, therefore data is filtered before generating the polygonal model. The filtering process typically consists of thresholding the data to eliminate most of the noise. A low pass filter is used to minimize the high-frequency noise that would produce an irregular bumpy surface when input to the algorithm. This filtering process produces a relatively smooth surface that approximates the scanned specimen and reduces the number of polygons generated due to noise. A unique filter was created for the heart data which only smoothed the data between scans, no other filtering was needed (see Figure 3). Due to the large number of slices in both heart and skull data sets, several models were made, each of which represented a small number of slices. To improve display performance a meshing algorithm was developed (meshit), that converted the raw collection of triangles into efficient strips. The triangle strips averaged over 100 triangles in size.

Generating Stereo Images

After the models were made, stereo sequences were rendered. To generate the sequences, a tool developed by IGOAL called OOM (Object Orientation Manipulator) was used. OOM (available through COSMIC) rendered each frame to disk. The images used red and blue color separation for representing stereo images . Once the sequence was recorded to disk it was converted frame by frame to Macintosh ".pict" format and transferred to a Mac (full color image sequences were also transferred to the Mac for non-stereo viewing).

Macintosh - Stereo Images and Multi-Media

The Macintosh was selected because it is a relatively affordable platform and has a wide base already installed in the school systems. It is a leading engine of desktop multi-media and has a wide array of software and hardware available for this task, though more is needed.

Once on the Macintosh, the images were edited to produce the desired effect, such as digitized cadaver overlays or text inserts describing what is being viewed. By using Apple's QuickTime extension, the images were then converted into QuickTime movies for animation on the Mac. The movies can also be edited on the Mac. To be able to view the stereo effects, the user must wear red/blue 3D glasses.

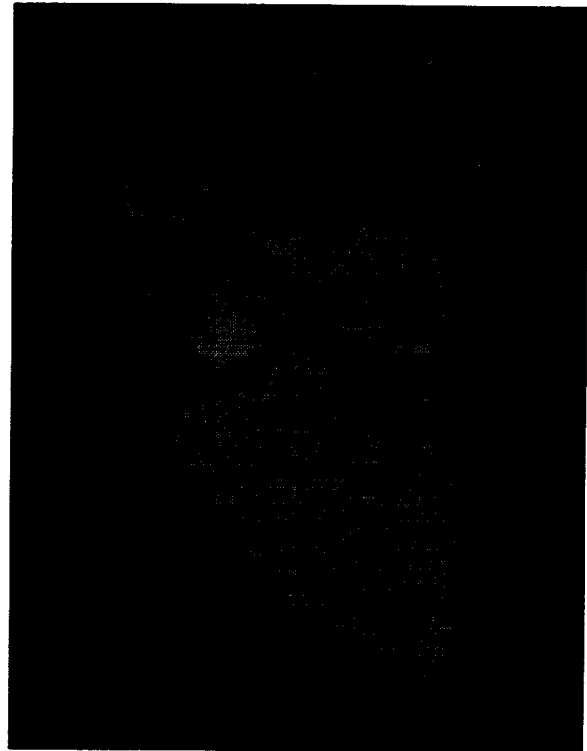**Figure 3**   3D Heart Model from MRI data

A Hypercard interface (a simple tool for creating prototypes) is being created to house the Educational Experience on the Mac. Other hypertext programs have been investigated and will eventually replace the Hypercard interface. Many forms of multi-media will be considered and then incorporated into the finished product including, but not limited to, a Virtual Reality head mounted display (HMD) or boom system, CD ROM, laser disc, audio, video, digital imagery, and 3D.

The VIVED application will contain lectures, supplemental text, graphics, digital movies, notes, pop quizzes, references, exams, Virtual Reality experiences of anatomy, student comments, bookmarks, qualitative analysis of student performance, summations, and program evaluations.

CONCLUSIONS

The VIVED project is at a point where CT scanned medical images of bone (e.g., the skull) can be generated into high quality VR imaging for prescribed fly-throughs on the Macintosh computer using a HMD or boom system. The project team is in the process of working on a heart VR model that has been generated from MRI data. Preliminary results indicate that a high resolution model can be developed using this type of imaging data. The project has been able to maintain its goal of high quality of VR imaging. This has led to some problems because of the amount of data the computer needs to deal with even during frame-by-frame sequencing of the prescribed fly-throughs. Alternative hardware and software options are being explored to deal with this problem.

Another problem has been the current status of technology for the display systems for HMDs. The LCD displays do not have the resolution needed to maintain a high quality VR experience. The CRT displays are reaching the resolution needed for the project, but the cost is prohibitive for multiple education platforms.

The next goal for the project include improving the software and hardware for generating VR images, developing prescribed fly-throughs and incorporating multi-media into the VR fly-throughs. Other anatomical imaging data will be obtained from CT scans, MRI and Cadavers to develop VR imaging of anatomical regions that contain different tissues with different data densities

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TECHNOLOGY TRANSFER OF OPERATOR-IN-THE-LOOP SIMULATION

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Abstract

The technology developed for operator-in-the-loop simulation in space teleoperation has been applied to the Caterpillar's backhoe and wheel loader, and off-highway truck. On a SGI workstation, the simulation integrates computer modeling of kinematics and dynamics, real-time computation and visualization, and an interface with the operator through the operator's console. The console is interfaced with the workstation through an IBM-PC in which the operator's commands were digitized and sent through a RS 232 serial port. The simulation gave visual feedback adequate for the operator in the loop, with the camera's field of vision projected on a large screen in multiple view windows. The view control can emulate either stationary or moving cameras. This simulator created an innovative engineering design environment by integrating computer software and hardware with the human operator's interactions. The backhoe simulation has been adopted by Caterpillar in building a virtual reality tool for backhoe design.

Key Words: Teleoperation, redundant manipulator, simulation, recursive dynamics

1. Introduction

Teleoperation [1,2] involves a human operator, a hand controller, and a manipulator, in which the manipulator under the operator's supervision completes tasks ranging from simple trajectory following to pick-and-put operation. The operator's interaction with the manipulator becomes a key issue, because of the intrinsic difference between a human operator and a robotic manipulator; that is, a human operator works more efficiently in Cartesian space [3] whereas most manipulators are designed with joint servo control.

For off-line trajectory analysis, the inverse position and orientation problem can be solved iteratively using inverse velocity/angular velocity solutions [4]. In teleoperation, however, the desired configuration of the end-effector is known only after the operator has commanded through the mini-master. This means that both Jacobian construction and inverse kinematic analysis must be completed on-line in real time. Unlike the Jacobian defined for the pre-determined end-effector's trajectory, the constraint Jacobian can be constructed on-line as the operator controls the manipulator's end-effector through the mini-master.

The constraint Jacobian is derived from the six constraints [5] that are imposed between the current and the desired end-effector's Cartesian position and orientation. The desired Cartesian position and orientation of the end-effector is viewed as the target that the current position and orientation will eventually have to assume. Constraining the two sets of position and orientation yields six constraints from which the constraint Jacobian is constructed [6]. This Jacobian and its pseudoinverse are used in iterations to yield the joint command angles necessary for the joint controllers. The procedure is illustrated with a Kraft 6-d.o.f. mini-master and a 7-d.o.f. redundant manipulator [7] and also with an operator's console and a backhoe.

Since the manipulator's dynamics involves kinematic redundancy and intermittent kinematic loop closure, the dynamic model is constructed in the recursive Newton-Euler dynamic formulation adapted for high-speed simulation of general constrained mechanisms [8,9,10,11,12]. According to d'Alembert's principle, this formulation starts out with the virtual work of all the links and the cut joint, where the cut joint is expressed in the Lagrange multiplier