Head-Mounted Display Research

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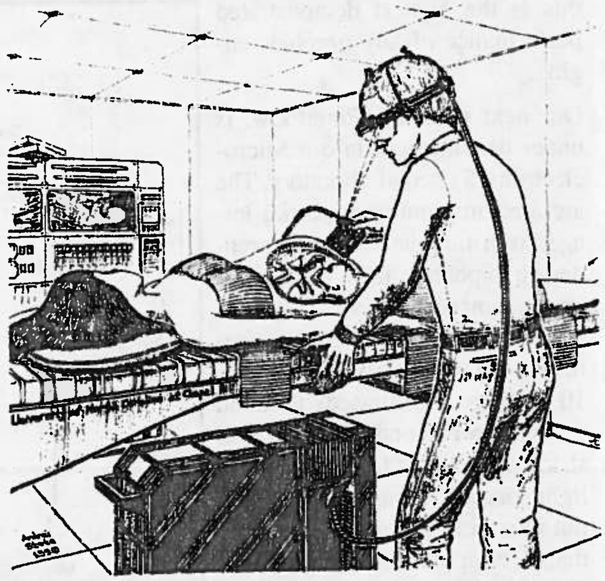
Introduction. Wearing a head-mounted display (HMD) gives a human user the sensation of being immersed in a three-dimensional, computer-simulated world. Because the positions of the head and hand are tracked by the system, the user can move through this virtual world, turn to look in any direction, and use a hand-held input device to interact with simulated objects. The image of the virtual world seen by the user is adjusted up to thirty times per second to correspond with the position and orientation of the user's head. The full-color, wide-angle, stereoscopic headgear provides a slightly different image to each eye so that the computer-generated environment appears fully three-dimensional to the user, and the wide-angle field of view gives him or her the feeling of being immersed in the simulated environment. The user hears sounds triggered by events in the virtual world, such as two simulated objects bumping into each other. The user can also feel forces and torques in the virtual world through the handgrip of a six-degree-of-freedom force-feedback subsystem, the Argonne Remote Manipulator (ARM).

The virtual world surrounding the user is defined by a graphics database, called a *model*, that gives the colors and coordinates for each of the polygons making up the virtual world. Some software, called the *simulation code*, controls the behavior of objects, the actions that can be performed by the user, and the initiation of sounds and forces in the virtual environment. One action often possible for the user is to "fly" through the virtual world using a manual input device to control direction and speed. The simulation code for some virtual worlds lets the user scale the world up and down or pick up simulated objects with the manual input device. Two people wearing HMDs can also enter into a shared virtual world, seeing and interacting with each other.

Goal. The goal of this project is to develop a multisensory HMD system, investigate methods of manual control suited to a HMD, and demonstrate the system's usefulness in real-world applications.

Applications. A HMD is most appropriate for applications in which the user needs to see three-dimensional data and which can benefit from the user's active exploration of the simulated three-dimensional space. As 3D spaces become more complex, the ability to explore them intuitively becomes more important. Some application areas in which we are conducting research are:



Architectural Walkthrough—Before a building is constructed, an architect and client can walk from room to room through a three-dimensional computer model of the planned building. In our current system the user views the building space through a HMD while "walking through" the virtual building under a 10' by 12' ceiling tracker that can be translated from room to room in the model. Architect and client can experience the space and adjust the building plans to solve problems before actual construction commences.

Molecular Modeling—Biochemists use computer graphics to understand the three-dimensional shapes of complex molecules such as proteins. The design of some classes of new drugs depends on finding drug molecules that fit into receptor proteins, like a key fits into a lock. The HMD and force-feedback device may help the biochemist look at, move, bend, and twist simulated molecules more effectively in order to better determine how they fit together.

Surface Science—Data from a scanning tunneling microscope is presented to the user as a colored surface floating in space. The user can control the microscope's tip by moving the force-feedback ARM and can feel forces indicating the location of the surface.

Radiation Therapy Treatment Planning—The HMD is well-suited to medical imaging because anatomical structures are complex three-dimensional objects. Using a HMD for planning the location and orientation of radiation beams to irradiate a tumor offers the possibility of more effective cancer treatment by more clearly showing the three-dimensional situation of the tumor and nearby healthy organs and tissue. Even though beams aimed at odd angles might be more effective in destroying tumors while preserving healthy surrounding tissue, radiation oncologists rarely use odd-angle beams, simply because today's flat computer displays make it difficult to visualize the precise placement of these odd-angle beams. Current research is investigating the possible advantages to be gained from using a HMD to target radiation treatment beams.

"Ultrasound Vision"—Another planned use of the HMD for medical imaging has been nicknamed "ultrasound vision." If the image data from a real-time ultrasound scanner is transformed to the viewpoint of a physician wearing the HMD, the physician will have the impression of seeing inside the tissue being scanned, with the ultrasound image optically superimposed onto his or her direct view of the patient. We are developing a new HMD with custom "see-through" optics that will allow superimposition of the computer-generated images onto the view of the physical environment. (One of our earlier HMD designs already had "see-through" optics, but its field of view was too narrow and its display devices too dim for effective long-term use.)

Hardware. For years the major impediment to the effectiveness of HMDs has been the primitive state of the required technologies: the image-generation system, the head and hand trackers, and the headgear itself (including the display devices and the viewing optics). We have been working to improve all of these except the display devices themselves.

Image generation—Pixel-Planes 5, the massively-parallel graphics engine developed here at UNC, generates video images to the left- and right-eye displays. In these applications, this machine renders over 100,000 shaded and textured triangles per second to the screen at rates of over 10 frames per second to each eye (peak performance has been observed at over 2 million triangles per second to a high-resolution (1280 x 1024 pixel) screen for a terrain flyover application). To our knowledge,