Chapter 11
Volume Visualization Using Virtual Reality
Medical Applications of Volume Rendering in Immersive Virtual Environments

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Abstract In this chapter we take a look at the possible applications of volume visualization in immersive virtual environments, and how they can be implemented. Nowadays, the availability of many kinds of 3D imaging modalities, like CT, MRI and 3D ultrasound, gives clinicians an unprecedented ability to look inside a patient without the need to operate. However, while these datasets are three dimensional, they are still presented on 2D (flat) screens. While most systems and workstations offer a volume rendering option to present the data, when projected onto a normal screen (or printed on paper or film), the images are not truly 3D and are often termed “2.5D.” By using a virtual reality system that immerses the viewer(s) in a truly three-dimensional world, we hope to improve the understanding of these images.

Introduction

With the invention of the CT scanner by Hounsfield and Cormack in the early 1970s, doctors were no longer limited to the flat, 2D world of X-ray imaging when they wanted to obtain information on the “insides” of their patients without operating on them. CT scanners allowed them to obtain a number of “slices” through the patient’s anatomy, essentially creating a rectangular volume of data describing the density of the tissues at a large number of points (also known as voxels) in three dimensions. This was a huge improvement over the X-ray photograph, which compresses all of the information on the third dimension into a flat image, making it impossible to tell what is in front of what.

In addition to the CT scanner, MRI and 3D ultrasound imaging modalities have now been introduced, which also generate volumes of data that image anatomy in three dimensions. However, 3D imaging technology is no longer limited to anatomy;
it also allows us to look at the actual biochemical processes taking place in the patient’s body, using, for instance, SPECT, PET and functional MRI (fMRI) scans.

When these imaging modalities were introduced, radiology departments were equipped to handle the X-ray films and the graphical capabilities of computers were almost nonexistent. Therefore, the only viable option was to examine the data volumes generated by the scanners by printing them slice by slice on film, and then examine them on light-boxes like ordinary X-rays. While light-boxes have since been replaced (initially) by dedicated workstations with CRT monitors and (more recently) with PCs and LCD panels, decades of radiological experience mean that even today the majority of radiological exams are still based on a slice-by-slice evaluation of the datasets. Only in a limited number of cases are volume visualization techniques used to render 3D views of the data, and even these are presented on what are essentially 2D media: either computer monitors or prints on paper. This means that in almost all cases, fully three-dimensional data is being reduced to two dimensions. To make matters worse, the manipulation of these images, normally with a computer mouse, is also restricted to 2D methods.

In this chapter we will try to show the added value of using so-called immersive virtual reality (VR) systems, which offer true 3D (stereoscopic) images and 3D interaction for the visualization and investigation of medical volumetric datasets. The best-known immersive VR systems are those based on a head-mounted display (HMD), also known as the VR helmet, that immerse the wearer in a 3D virtual world by placing small screens (typically LCD panels a few inches in size) right in front of the eyes. While current display technology can provide images of high enough quality for most applications, HMDs still have two major drawbacks: first and foremost, by shutting out the “real world” they prevent meaningful collaboration with other people, as interaction between avatars in the virtual world is still severely limited with current technology; second, despite increases in image quality and responsiveness, the users of HMDs frequently experience a condition known as “simulator sickness,” an affliction not unlike motion sickness, where the user is affected by nausea and dizziness. To overcome these drawbacks, the Electronic Visualization Laboratory of the University of Chicago developed the concept of the CAVE™ (Cruz-Neira et al. 1993) in the early 1990s.

Systems like the CAVE™ immerse viewers in a virtual world by surrounding them with three-dimensional (i.e., stereoscopic) computer-generated images. The images are projected onto the walls, floor and sometimes ceiling of a small “room” in which the observers stand. Current LCD and DLP projection technology allow high-resolution images with a considerable dynamic range to be projected onto screens ranging from 2.5 to 4 m wide. The stereoscopic effect can be attained by using a passive system with filters (based on either polarization or color shifts) that simultaneously projects the left and right images, or an active system that alternately projects the left and right images and uses LCD shutter glasses to separate the images. The head position of one of the users is usually tracked by an electromagnetic or optical tracking system, which allows the system to provide that particular user with the correct perspective. As the images are generated in real time, this also generates so-called motion parallax, which further enhances depth perception.