A Vision for Visualization in Medicine

The practice of medicine has always relied upon visualizations to study the relationship of anatomic structure to biologic function and to detect and treat disease and trauma which disturb or threaten normal life processes. Traditionally, these visualizations have either been direct, via surgery or biopsy, or indirect, requiring extensive mental reconstruction. The revolutionary capabilities of new 3-D and 4-D medical imaging modalities (CT, MRI, PET, US, etc.) along with computer reconstruction and rendering of multidimensional medical and histologic volume image data, obviate the need for physical dissection or abstract assembly of anatomy, and provide powerful new opportunities for medical diagnosis and treatment. Minimally-invasive or non-invasive interventions are now within reach which effectively increase physician performance in arresting or curing disease, which reduce risk, pain, complications and re-occurrence for the patient, and which decrease healthcare costs.

Most current medical interventional procedures (e.g., surgery, biopsy, catheterization) still require "blind" approaches (i.e., the clinicians cannot directly see the target and/or pathway to the target during the procedure), or if visualizations are available, they are limited to 2-D, slow and/or off-line displays. These procedures also often depend on gross approximations and estimates of target position and orientation based on indirect measurements (e.g., EKG). Interactive visualization and Virtual Reality (VR) technology open new realms in the practice of medicine by permitting the images obtained from modern medical imaging systems to be directly displayed and manipulated with intuitive immediacy and with sufficient detail and speed so as to evoke sensorial experience similar to that of real experience. VR allows physicians to "enter" the visualizations, to take up any viewpoint, to see dynamic functional processes, as well as detailed anatomy, to make accurate on-line measurements, and to manipulate and control interventional processes. The ultimate value of VR in medicine will derive more from the sensory enhancement of real experience than from the simulation of normally-sensed reality. Visualized objects extend across a vast range of scale from individual molecules and cells through the varieties of tissue and interstitial interfaces to complete organs, organ systems, and body parts, and include functional attributes f these systems, such as biophysical and physiological properties. Medical applications include accurate anatomy and function mapping, enhanced diagnosis, and accurate treatment planning and rehearsal. However, the greatest potential for revolutionary innovation in the practice of medicine lies in direct, fully immersive, real-time multisensory fusion of real and virtual information data streams during an actual clinical procedure. Such technology is under development in our laboratory, but not yet available to the medical practitioner. We plan to further develop, validate and disseminate products based on this technology. The effort will benefit from advanced computer image processing research which has recently facilitated major progress toward fully interactive visualization and simulation. With these advances in hand, there are several important clinical applications possible to deliver now that will have a significant impact on medicine.

Some of the most complex and challenging applications, those which show the greatest promise of significantly changing the practice of medical diagnosis and treatment, have begun to be explored in our laboratory. These include advanced procedures for coronary stent placement and evaluation of cardiac plaques, cardiac ablation therapy, neurosurgery rehearsal and intra-operative guidance, prostate biopsy guidance and analysis, bronchoscopy and colonoscopy, and anesthesia delivery. Preliminary results suggest that in these applications virtual procedures can provide accurate, reproducible and clinically useful visualizations and minimally invasive interventions. They demonstrate significant promise for improving physician performance, minimizing patient risk and morbidity, and reducing health care costs.