True 3D Virtual Reality Visualization for Diagnostic Imaging and Treatment Planning in Cardiovascular Diseases

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Introduction

Three-dimensional reconstruction of medical imaging information is increasingly used to present anatomical structures and pathologies for the purposes of diagnosis and treatment planning. This trend is driven by (1) the availability of high-resolution 3D- or 4D-data set from CT, MRI, and ultrasound, (2) the desire to consolidate the large amount of data and focus on the relevant information about the disease, and (3) the need to present the imaging information in a cognitively intuitive way to facilitate communications.

Currently, 3D reconstruction techniques, such as volume rendering, emulate how a 3D object would appear on a two-dimensional screen. This restriction limits the full use of our spatial senses, thereby, introducing ambiguity and uncertainty (Fig. 1). To overcome this limitation, two approaches are being developed. One is 3D-printing and the other is 3D-virtual reality.

Fig. 1, A volume rendering of an aortic coarctation. Are we seeing the convex surface of the aortic exterior or the concave surface of the aortic lumen?

In this poster, we describe one implementation of 3D-virtual reality, the True3D technology developed by EchoPixel, and explore its medical applications. We will also discuss the respective roles of 3D-virtual reality and 3D-printing.

True3D System and Sensory Cues

The True3D system (Fig. 2) consists of a pair of specially marked spectacles with two orthogonally polarized lenses. A set of cameras tracks the markings to determine the position and orientation of the observer's head. A spatially tracked pointing device lets the hand interacts with the virtual world. A computer gathers these inputs and calculates the appropriate right and left eye images. These are displayed on a polarized monitor to be viewed through the polarized spectacles, completing the loop.

Fig. 2. The True3D system in use.

Three types of sensory cues help produce the 3D cognitive experience (Figs. 3-5).

Fig. 3, Sterescopic parallax relies on different input to the left and right eyes to produce depth perception.

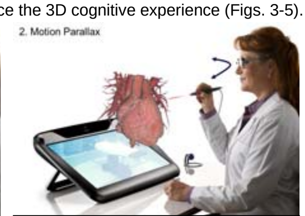

Fig. 4, Motion parallax presents different aspect of the object by movement of the head.

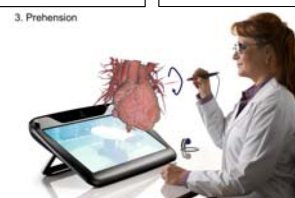

Fig. 5, Prehension integrates hand-eye coordination to uncover hidden portion of the object.

Diagnostic Radiology Applications

For a radiologist, much of his training is spent on correlating memorized 3D human anatomy with medical images of any source or presentation. The anatomy knowledge helps him predict what is not in view. This skill breaks down when the anatomy is variable or unexpected. It is in these cases that True3D is most helpful to the diagnostic imager (Figs. 6-7).

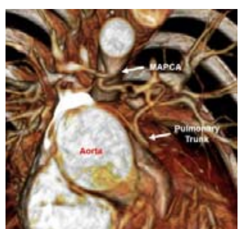

Fig. 6, volume rendering of a case of pulmonary atresia with major aortopulmonary collateral arteries (MAPCA). The tiny central pulmonary arteries and MAPCAs both perfuse the lungs. The vascular connections are unique to each patient.

Fig. 7, the left eye and the right eye images for the MAPCAs in Fig. 6.

A suite of processing tools, including programmable transfer function, color map, interactive cropping tool and cut plane, and 4D-cine, allow effective evaluation of interior structures of the heart (Fig. 8).

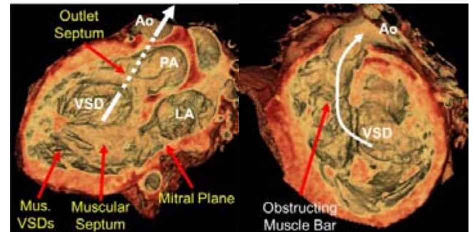

Fig. 8, complex congenital heart disease. A one year old boy born with double outlet right ventricle with transposed great arteries. The right ventricular outflow tract is obstructed by a muscle bar.

Interventional Planning and 3D Guidance

Most procedures performed by interventional radiologists, interventional neuroradiologists and interventional cardiologists are guided by fluoroscopic projectional images. True3D can help navigate complex vasculature for the purposes of embolization, stenting, and drug delivery (Fig. 9). Measurement tools assist in sizing of stent, stented valve, and other endovascular devices before the interventional procedures (Fig. 10).

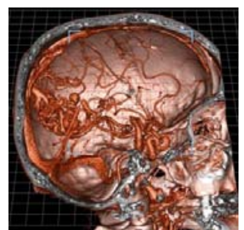

Fig. 9, cerebral AVM with complicated feeding arteries and draining veins. Planning for embolization requires precise knowledge of the vascular connections, aneurysm, and region of the brain involved.

Fig. 10. (top) Pipeline™ Flex Embolization device (Medtronic), and (bottom) treatment of a giant aneurysm. The width and length of the device must be sized correctly for effective exclusion of the aneurysm. These measurements can be done effectively on the True3D system.

Surgical Planning and Intraoperative Guidance

Deployment of the portable True3D system in the operating room allows intraoperative imaging consultation during surgery. Simulating surgical anatomy, the True3D presentation is effective conveying patient specific information to the surgical team. At Stanford, the True3D system has been used for separation of conjoined twin, for complex pulmonary artery reconstruction, and for sternotomy planning before minimally invasive valve replacement surgery (Fig. 11).

Fig. 11, intraoperative examination of anatomic structures of the chest. In minimally invasive valve replacement surgery, a limited sternotomy is made just large enough to gain access for cardiopulmonary bypass cannulations and to replace the defective valve. True3D helps determine the precise location for the sternotomy.

True3D Visualization Versus 3D Printing

Virtual reality and 3D printing are two approaches that produce 3D cognitive experience. Each approach has its advantages and disadvantages, and in some applications, they complement each other. True3D allows immediate examination of a study without waiting for the model to be printed, and it does not require segmentation, a time consuming process. The cut plane, scale, color, and surface texture for a physical model are fixed once it is printed, while these factors can be changed at will and in real-time in True3D. Finally, True3D can demonstrate motion by running a movie. This is not possible with a printed model.

A printed model does offer tactile feedback better than current implementation of True3D. Furthermore, a model can be produced to test fit a device physically, while this cannot be done with True3D.

The best approach may be to combine both. True3D can be used first to explore the data set and plan out the optimal cut plane and segmentations. The results can then be transferred electronically for 3D printing.

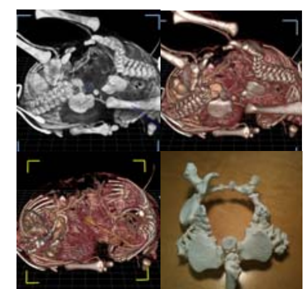

Fig. 12, a pelvic conjoined twin. (Top R) True3D in skeletal rendering, (Top L) True3D in vascular rendering, (Bottom R) Explore with cut plane, (Bottom R) 3D printed model.