Virtual and Augmented Reality Visualization and Guidance for Minimally Invasive Surgery

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The Challenge

Our research group develops and operates visualization and guidance systems for minimally invasive procedures. In addition to stereoscopic head-tracked displays, we use augmented reality (AR) to allow physicians to see directly into patients. AR combines computer graphics with images of the real world. This can be accomplished through the use of ultrasound echography imaging, 3D laparoscopic reconstruction, video see-through head-mounted displays (HMDs), and accurate motion tracking, creating live images that combine computer-generated graphics with the physician's live view of a patient. A mature AR system displaying live ultrasound data or hybrid laparoscopic video/range data (see simulated image below) in real time and properly registered to the patient could be a powerful and intuitive tool, applicable to various ultrasound-guided and laparoscopic procedures.

A laparoscopic surgery with a computer-generated virtual incision appears to the surgeon like an open procedure (InnerOptic simulation).

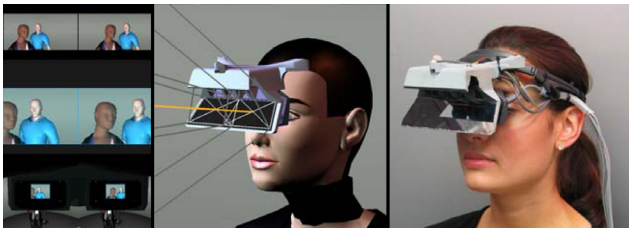
Our human subject studies serve as driving problems toward improving virtual and augmented-reality technologies such as tracking, HMD systems, and visual representation. We believe that the use of VR and AR technology can significantly simplify both learning and performing minimally invasive interventions. Initial experiments have shown the promise of our techniques but have also pointed out problems that must be overcome before realizing a clinically useful system.

The Approach

Our prototype systems use real-time video capture and image synthesis, combined with opto-electronic and mechanical motion tracking. The software runs on off-the-shelf personal computers. We design and construct hardware such as motion tracking devices and video see-through head-mounted displays (see following images). We test our systems on commercial and custom-designed anatomical phantoms, as well as on animals and on human patient volunteers.

Highlights

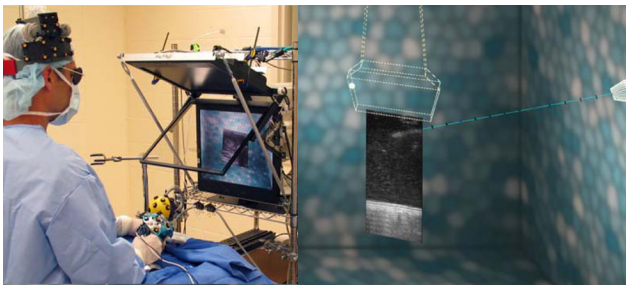
- **Project uses virtual- and augmented-reality technology to assist physicians with certain types of minimally invasive procedures.**
- **Project pushes the envelope of motion tracking and stereo displays, including video-see-through head-mounted displays.**
- **Interdisciplinary collaboration between computer scientists and medical professionals.**
- **We research and develop complex virtual and augmented reality systems and test them in laboratory experiments, sometimes with animal and human subjects.**



Custom-designed video see-through head-mounted display.
Left and center: computer simulation. Right: finished, operational device.

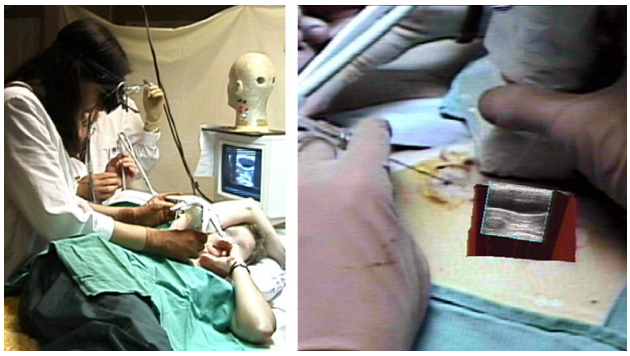
Radio-frequency Ablation of Liver Tumors. This technique is used on patients with life-threatening, inoperable liver tumors and can significantly prolong patients' lives when successful. Most recurrences appear at tumor margins, making accurate targeting of the ablation probe highly critical. With funding from the National Cancer Institute, we are currently developing and testing a virtual reality guidance system for liver RFA procedures (see images below).

Accurate targeting is also crucial for very large tumors, which have to be ablated with multiple overlapping passes, a complex 3D positioning task. We expect 3D visualization and guidance to provide valuable assistance with such procedures, leading to improved patient care.



3D guidance system for liver function ablation. Left: system in use on a wood-chuck, with head-tracked stereoscopic display mounted above patient.
Right: view inside the display.

Ultrasound-Guided Biopsy of Breast Lesions. This diagnostic method has partially replaced open surgery. Ultrasound guidance is also used for needle localization of some lesions prior to biopsy, and for cyst aspiration (see images below). The conventional variant requires excellent hand-eye coordination and 3D visualization skills to guide the needle to the target area using non-registered sonograms. Our research showed that AR guidance can improve targeting accuracy over the conventional method, even for highly skilled practitioners.



Breast cyst aspiration with AR guidance. Left: Dr. Etta Pisano (Chief of Breast Imaging) with patient. Right: Dr. Pisano's view in the HMD.

Current Project Members

Henry Fuchs (Principal Investigator), Federico Gil Professor
Andrei State (Technical Lead), Senior Research Scientist
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Medical and Veterinary Collaborators

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Selected Publications

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Keywords

Virtual reality; augmented reality; medical visualization; head-mounted display; stereoscopic display; head-tracked display; motion tracking; registration; ultrasound echography; laparoscopy; minimally invasive surgery; radio frequency ablation

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