Augmented-Reality Medical Visualization Research

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The Challenge

Our research group is working to develop and operate a system that allows a physician to see directly inside a patient, using augmented reality (AR). AR combines computer graphics with images of the real world. This project uses ultrasound echography imaging, laparoscopic range imaging, video see-through head-mounted displays (HMDs), and high-performance graphics computers to create live images that combine computer-generated graphics with live video images of a patient. Our system displays live ultrasound data or hybrid laparoscopic video/range data in real time and properly registered to the part of the patient that is being scanned. Such a powerful and intuitive tool could be used to assist and to guide physicians during various types of ultrasound-guided and laparoscopic procedures.

Our group's human subject studies serve as driving problems toward improving augmented-reality technologies such as tracking, HMD systems, and visual representation. We believe that the use of 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.

Highlights

- **Project uses augmented-reality technology to assist physicians in performing certain types of minimally invasive surgical procedures.**
- **Project pushes the envelope of tracking and head-mounted display (HMD) technologies, in particular video-see-through HMDs.**
- **Computer scientists conduct interdisciplinary research in collaboration with medical professionals.**
- **Project members develop complex augmented-reality systems and test them in laboratory experiments, sometimes with human subjects.**

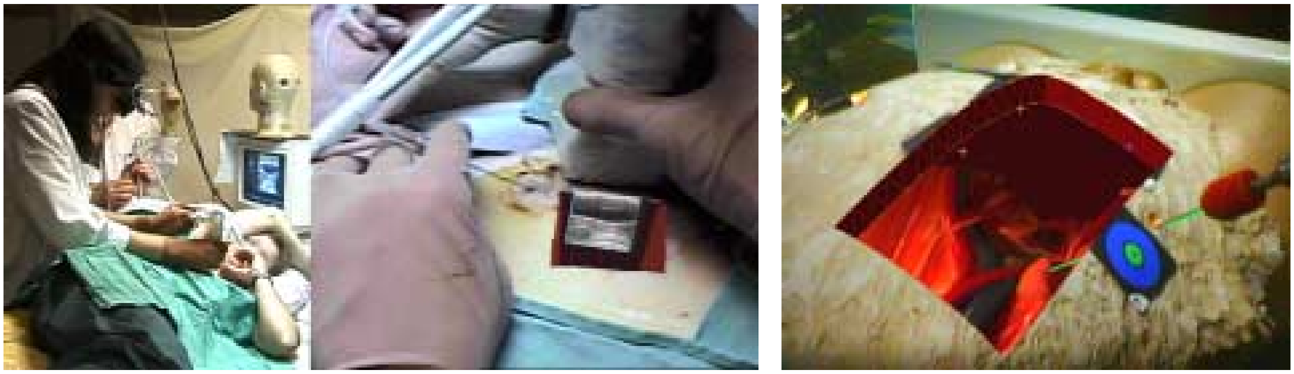
The Approach

Hardware and Software for Augmented Reality Visualization. Our real-time AR system runs on the department's SGI Reality Monster, a high-performance graphics supercomputer. We make use of the digital video input capabilities of the Reality Monster by simultaneously capturing imagery from the HMD cameras and from the ultrasound imager into texture memory. The camera video is textured on polygons occupying most of the user's field of view; the ultrasound video images are textured on translucent polygons emitted by the ultrasound probe inside a computer-generated opening within the scanned patient. The polygons fade away in time, controlled by a user-definable half-life parameter. A large number of such directly rendered ultrasound slices can give the appearance of a volume data set. The user's head-mounted display and the hand-held ultrasound transducer are tracked by optoelectronic tracking devices. Additional video streams and tracked instruments can be incorporated into the system for laparoscopic visualization experiments.

Ultrasound-Guided Breast Biopsy. In recent years, ultrasound-guided biopsy of breast lesions has been used for diagnostic purposes, partially replacing open surgical intervention. Ultrasound guidance is also often used for needle localization of some lesions prior to biopsy, as well as for cyst aspiration. With conventional technology, one needs excellent hand-eye coordination and 3D visualization skills to guide the needle to the target area with the aid of non-registered sonograms. We believe that AR can help with learning and performing breast biopsies. Our current research focuses on perfecting an AR system that will aid a physician in performing a breast biopsy and the similar procedure of cyst aspiration.

Video see-through HMD built from a modified Sony Glasstron high-resolution stereo unit, equipped with miniature video cameras aligned to the wearer's eyes via mirrors. Left: Parametric design simulation. Right: Finished device (photo by Caroline Green).

Research Directions. New applications of our technology require advances in tracking, image processing, and display devices. In collaboration with the University of Utah, we designed and built a video see-through HMD and are continually experimenting with see-through HMD designs as well as alternatives to HMDs. Commercially available trackers limit our ability to precisely register real and synthetic



Experiments with the medical augmented reality system. Left and center: Ultrasound-guided breast biopsy performed by Dr. Etta Pisano, M.D., head of Breast Imaging at UNC Hospitals; and the view through the HMD. Right: The HMD view during an experiment that simulates a minimally invasive laparoscopic procedure. The red-colored, computer-generated opening into the patient shows the internal organs. A tracked needle (green line) is used to target a small lesion within the abdomen.

imagery, which has led to research into improving tracking systems. As we began to develop our system for laparoscopic surgery, we found it necessary to develop instruments—such as a 3D laparoscope capable of acquiring video images as well as depth—and algorithms for rapidly extracting the 3D geometry inside a body cavity.

User interface of complex augmented reality system.

Project Leaders

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Selected Publications

Rosenthal, M., A. State, J. Lee, G. Hirota, J. Ackerman, K. Keller, E. D. Pisano, M. Jiroutek, K. Muller, and H. Fuchs. "Augmented Reality Guidance for Needle Biopsies: A Randomized, Controlled Trial in Phantoms," *Proc. Medical Image Computing and Computer-Assisted Intervention 2001*, 240–248.

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Key Words

Augmented reality; 3D medical visualization; head-mounted display; video see-through head-mounted display; registration; ultrasound echography

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