CPSC 533C Proposal
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The Use of Augmented Reality in the Operating Room: a Review

John Bartlett (jbart@interchange.ubc.ca)

Description of Task

Although medical imaging technology has existed for over a century, its use is still mostly limited to diagnostic purposes. Technological advancements in the past few decades have led to images with higher contrast, better spatial resolution and less noise, but these are often pushed aside when it is time to perform surgery.

This is not to say that surgeons don't make use of medical imaging. On the contrary, preoperative planning allows the surgeon to formulate a strategy for the procedure and anticipate potential problems. However, it would be advantageous if this information could be presented not simply as a reference, but mapped onto the surgeon's field of view to provide an augmented reality interface. This would enable the surgeon to rapidly locate important structures during time-critical stages of the operation while avoiding sensitive nerves and vessels.

This is where information visualization work is needed. Scientists and engineers have developed the necessary tools to acquire and process images, but we need to answer the question of how to best present this information in the operating room. A solution to this problem will require extensive cooperation between the medical imaging and infovis communities. The goal of the proposed survey is to consolidate the knowledge relevant to this field and bridge the gap between problem-driven and technique-driven research. The report will provide a complete perspective on how augmented reality is used in surgery today and what challenges it faces in the future.

Personal Expertise

I have some background in medical imaging, starting with my undergraduate degree in biomedical computing from Queen's University. This summer, I started a research assistantship in an electrical and computer engineering lab at UBC that focuses on applications to medical imaging and surgery. For my MASc, I am looking for ways to use intraoperative ultrasound imaging to align preoperative CT images with the patient in real time. Even when this task is complete, the question of how to best incorporate the CT information into the surgeon's field of view may remain unanswered. Much of the ongoing research in my lab is of a similar nature, thus a better understanding of the available options in augmented reality could be very beneficial.

Scenario of Use

In order to gain perspective on my research, I observed a robotic laparoscopic surgery with tumour excision earlier this fall. The surgeon controlled the robot through a console on one side of the room using hand controls and a stereoscopic display. This allowed a magnified view inside the patient, but no medical imaging was used to augment the view. This information was clearly available, however, as a detailed 3D CT of the patient's abdomen cycled through its slices on a display on the back wall.

Being familiar with my project, the surgeon made a point of indicating what parts of the procedure would benefit most from incorporating new information. Locating the desired structure in the abdomen took approximately 30 minutes of tediously cutting away fat and connective tissue while avoiding injury to nerves and vessels. This process could be significantly shortened if the appropriate path was indicated using augmented reality.

After the site of the tumour had been located, the surgeon had to determine where to make the cut. Although cancerous tissue has different properties than normal tissue, as shown in several medical imaging modalities, they can appear quite similar to the naked eye or when observed by camera. At this point, the surgeon consulted the CT display and discussed his options with another surgeon that was present. This information should be made available in the surgeon's field of view to ensure that cuts are made optimally.

In robotic surgery where a console is used, the stereoscopic display is a suitable interface where augmented reality could be incorporated. In other procedures, semi-transparent displays have been used to overlay information on the surgeon's field of view using mirrors or a head-mounted apparatus to ensure the information is shown in the correct orientation. In any case, the added information should require minimal involvement on the surgeon's part to avoid complicating the procedure. The surgeon will have a switch to activate the augmented reality as needed, and perhaps additional tools to control settings such as transparency and depth.

Milestones

Week 9 - Gathering phase: Approximately 6 hours should be spent collecting research material from a wide variety of sources to ensure the survey has adequate breadth and depth. Begin reading.

Week 10 - Prepare project update based on most salient papers. Continue reading.

Weeks 11 and 12 - Reading phase: Continue reading papers (estimating approximately 40 in all), taking notes to facilitate writing later on.

Weeks 13 and 14 - Writing phase: Determine overall document structure, then write review (approximately 25 hours). Look for common ground between problem-driven and technique-driven research. Summarize paper in presentation.

Previous Work

Minimally-invasive surgery is advantageous in that it leads to a reduction in surgical complications, operating times, and patient recovery times. However, this strategy limits what the surgeon is able to see and increases the difficulty of the procedure. What is needed is a way to increase the amount of information that is visible to the surgeon, using data from medical imaging modalities such as CT, MRI and ultrasound [1].

There are a variety of ways in which this information could be presented. In a paper by Wang *et al.* [1], a 3D MRI reconstruction of a heart was integrated into the stereoscopic display on a da Vinci robotic surgical system. The heart model was successfully incorporated into the image, but the alignment was too poor to be useful in surgery. No user studies were mentioned, likely due to the fact that the results showed a need for refinement.

An older technique, described in a paper by Lorensen *et al.* [2], involves registering 3D imaging data with a live video feed of the patient for surgical planning. This study was successful in that it allowed the surgeon to map the location of a brain tumour onto the patient's head before beginning the procedure. However, this information was presented on a screen and not directly in the surgeon's field of view, so the surgeon had to look back and forth to make comparisons between the augmented reality interface and the patient.

Schwald *et al.* [3] describe an augmented reality implementation that they named the AR Window, a semi-transparent display that projects medical imaging data directly into the surgeon's field of view. Where similar devices use a half-silvered mirror to ensure the correct perspective, the AR Window uses eye-tracking technology. The paper serves mainly as a proof of concept, so more research is required to determine whether the display's usefulness outweighs its obstructive interface.

Finally, we can consider head-mounted displays, probably the most obvious way of influencing the surgeon's field of view. Fuchs *et al.* [4] developed a tracked head-mounted system with 3D visualization that was able to enhance the surgeon's natural point of view and preserve motion parallax. Currently, depth acquisition is too slow for surgical integration of this device to be feasible. The paper is also lacking a discussion of the practicality of the head-mounted display with respect to limitations on peripheral vision and restriction of motion due to bulkiness.

I expect that other techniques will emerge as I dig deeper into the literature, but I am hoping that I can at least provide a detailed analysis of the four methods discussed here: stereoscopic display for teleoperators, separate display, semi-transparent screen and head-mounted-display.

References

1. D.A. Wang, F. Bello, A. Darzi. Augmented reality provision in robotically assisted minimally invasive surgery. *International Congress Series.* 1268(2004): 527-532.

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3. B. Schwald, H. Seibert, T. Weller. A flexible tracking concept applied to medical scenarios using an AR window. *Proceedings of the International Symposium on Mixed and Augmented Reality*. 2002.

4. H. Fuchs, M.A. Livingston, R. Raskar, D. Colucci, K. Keller, A. State, J.R. Crawford, P. Rademacher, S.H. Drake, A.A. Meyer. Augmented reality visualization for laparoscopic surgery. *Proceedings of the First International Conference on Medical Image Computing and Computer-Assisted Intervention.* 1998: 934-943.