Data Integration During Robotic Ultrasound-Guided Surgery

Paper Seminar by Tifany Yung | Team 9

Partners: Vineeta Khatuja, Andrew Wang
Mentors: Michael Choti MD MBA, Theodoros Katsichtis, Colin Lea, Russell Taylor PhD

1. Project statement

Our project seeks to develop a new user interface for the Da Vinci surgical system console to allow greater data integration in order to provide the surgeon with more patient information during the surgery (Figure 1). The new interface will include the integration of live ultrasound feed and an image browser to view saved ultrasound images. Other features would include the ability to view preoperative images and construct 3D models of organs and other anatomical structures from those images. We will also perform a clinical user study to determine the surgeons' response to the new layout and features.

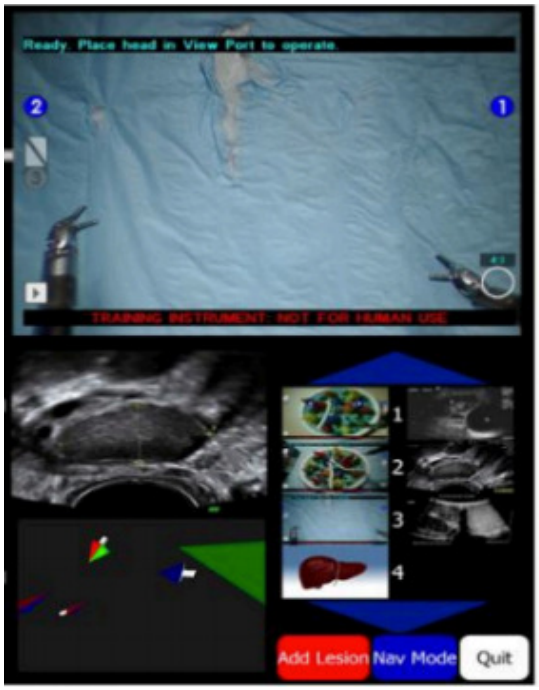

Figure 1. Our project's current interface.
Colin Lea '12. Interface for Robotic Laparoscopic Ultrasound (presentation).

2. Paper selection

Francesco Volonté, N. C. B., François Pugin, Joël Spaltenstein, Boris Schiltz, Minoa Jung, Monika Hagen, Osman Ratib, Philippe Morel (2012). "Augmented reality to the rescue of the minimally invasive surgeon. The usefulness of the interposition of stereoscopic images in the Da Vinci robotic console." The International Journal of Medical Robotics and Computer Assisted Surgery.

This paper was selected because of its study of the potentials and benefits that enhanced reality could contribute to robotic surgeries. Our project essentially deals with the development and testing of an enhanced reality interface, and this paper describes for us the usefulness of having immediate access to preoperative studies and findings, as well as what kinds of information in particular would best aid surgeons with more complicated kinds of procedures.

3. Summary of problem and results

3.1. The problem

To date, there has been little focus on integrating an enhanced reality environment with robotic surgeries. Many surgeons have been trained in the use of robotic surgical systems, but most only use a live camera feed from one of the robot's end effectors. Preoperative images are still kept outside of the immediate operating field, and surgeons must leave the console in order to consult them. This distracts the surgeon from the procedure and increases the risk of the surgeon committing an error.

3.2. The objective

The authors aim to create an enhanced reality environment that would provide live feed from the Da Vinci camera at the top of the console screen, while additional information is provided to the surgeon in the bottom half of the screen. The additional information would include such data as patient preoperative scans and 3D anatomical renderings for the surgeon to consult during the procedure.

3.3. The key results

The authors found that the surgeons were much more comfortable with performing a procedure when they had immediate access to the preoperative studies and patient information provided by the enhanced reality interface. The authors also found that displaying preoperative images next to the live camera feed also aided the surgeons to more easily complete a procedure.

4. Significance

Enhanced reality environments open up a new frontier in robotic surgeries. Not only does the Da Vinci robot provide the surgeon with physical assistance and fine-tune the surgeon's technique by reducing hand tremors and spasms, but an augmented reality interface would also provide quicker and more direct access to additional patient information and studies that the surgeon may wish to consult during a procedure. Having access to this information right next to the live camera feed would help the surgeon to complete the procedure more safely and successfully by allowing the surgeon to stay at the console and not be distracted from the surgery by having to leave the operating field to consult preoperative studies being stored elsewhere.

With the future successful implementation of enhanced reality environments, surgeons will need to learn to adapt to a split-screen console view and to switching between the full camera and integrated views. However, this method of data integration with the surgical console will provide surgeons with more information at their fingertips during a procedure.

5. Background

Enhanced reality environments are modified displays that integrate additional data for the surgeon's use during a procedure (Figure 2). Generally, these interfaces can provide access to a patient's preoperative scans and findings for immediate access during a procedure. The top half of the console display is reserved for the Da Vinci live camera feed, which usually takes up the entire screen in a standard Da Vinci robot system. The bottom half of the screen is taken up by the user interface of the console. What kinds of information and how it is presented in this interface is dependent on the individual developer, but the interface can house such features as an image browser, DICOM viewer for CT images, 3D image volume renderings, note-taking on images, etc.

Throughout the procedure, the surgeon can choose to display either the full-screen view of the live Da Vinci camera feed or the split-screen view of the camera feed and user interface. The interface can generally be controlled using the Da Vinci end effectors or another hardware component installed on the Da Vinci robotic system.

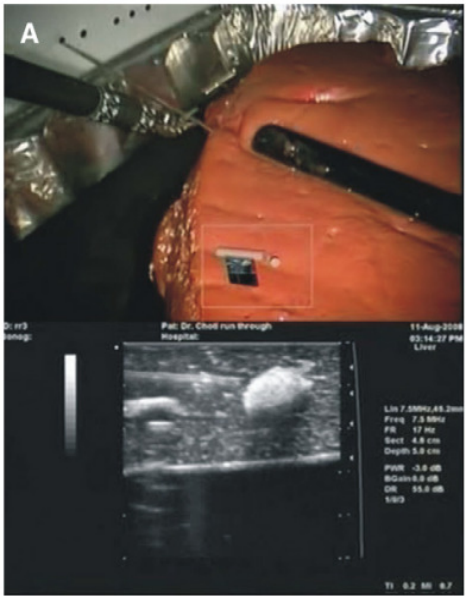

Figure 2. General enhanced reality interface.
Caitlin M. Schneider '12. Robot-assisted laparoscopic ultrasonography for heptic surgery.

6. Materials and method

6.1. Features implemented

To develop the enhanced reality interface, the authors implemented the rendering and display in the Da Vinci console of 3D volume-rendered anatomical images derived from the CT scans, the ability to import the patients' data for the surgeon to view, ability to modify rendering parameters, and the ability to add annotations to regions of interest.

6.2. Generation of stereoscopic images

The freeware OsiriX was used to generate the volume renderings to be displayed in the enhanced reality interface. Volume renderings were obtained by importing patient CT data into the OsiriX DICOM workstation. Since OsiriX has already implemented features to create, annotate, and display 3D images rendered from CT scans, the authors chose to integrate OsiriX with the Da Vinci system, rather than re-implementing the features. A custom OsiriX (9) plugin was used to stereoscopically display the 3D images on the Da Vinci console. In order to connect the OsiriX workstation and the surgical console, the computer was merely connected to the Da Vinci in order to project the interface onto the console. A 3D joystick was installed on the surgical robot to allow the surgeon to navigate the interface.

6.3. Display of stereoscopic images

In order to actually display the renderings as stereoscopic images on the console screen, TilePro was used to slightly different images to each of the surgeon's eyes, just as human eyes each receive a slightly different visual stimulus that allows the brain to process the differences and generate a 3D image.

To mimic this effect, TilePro DVI ports are connected to virtual monitors named DA_VINCI_LEFT and DA_VINCI_RIGHT, which send information as normal 1080p computer monitors. Each monitor appears before one of the surgeon's eyes to create the stereoscopic image. Activation of TilePro reduces the Da Vinci live camera feed to the top half of the console display while the stereoscopic image appears at the bottom half of the screen.

6.4. The patients

A clinical study was performed on the enhanced reality created by the authors using five patient procedures. Two of the patients suffered from symptomatic gallstone disease and underwent a cholecystecotomy to remove the gallstones from their gallbladder or biliary tract. Gallstones in the gallbladder may pass to other parts of the biliary tract such as the common bile duct. The obstruction of bile flow by one of these leads to abdominal pain and infection. One patient had a right colectomy, where a surgical resection of the tumors and surrounding tissue occurred to treat colon cancer. The remaining two patients underwent sigmoidectomies to remove their sigmoid colons (Figure 3) to treat malignant tumors.

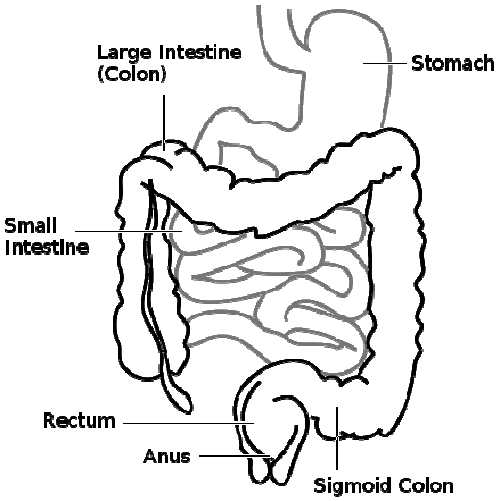

Figure 3. The colon and sigmoid colon.
http://en.wikipedia.org/wiki/Colon_%28anatomy%29

7. Results

7.1. Enhanced reality for a cholecystecotomy

Osirix successfully allowed the 3D reconstruction and intraoperative display of anatomical structures using the patients' preoperative CT studies. The surgeons performing the procedure cited the usefulness of being able to view the spatial locations of the biliary tree and its surroundings (Figure 4). Another benefit of the integrated data was the ability to grab and turn around structures in the enhanced reality interface in order to better examine their shape and form.

In order to gain a more objective indication of the surgeon's comfort with using the augmented interface, the total amount of time that the surgeon spent viewing the integrated data was also calculated. Over the course of each symptomatic gallstone procedure, the surgeon referred to the volume renderings multiple times for a few seconds each and totaled approximately five minutes over the entire procedures.

This was deemed to be an indication that the surgeon felt the enhanced reality to be helpful and beneficial to the procedure, as he would not have spent so much time displaying the images if he did not believe so.

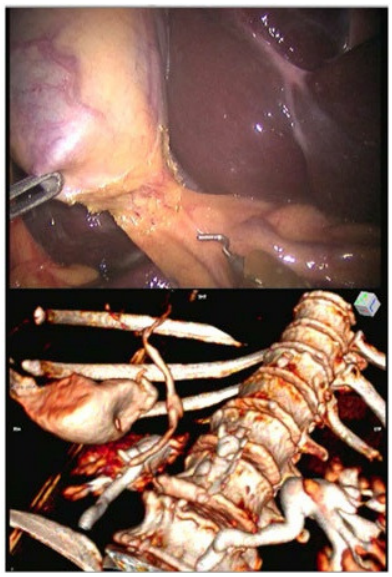

Figure 4. TilePro-activated interface showing the camera feed on top and the reconstructed images on the bottom.
Francesco Volonté '12.

7.2. Enhanced reality for a right colectomy

A virtual 3D colonoscopy was successfully displayed in the augmented reality interface in order to aid the surgeon with tumor location. The virtual colonoscopy allowed the surgeon to view the locations of the tumors to be removed with respect to the tumors' surroundings so that the surgeon could better compare it with the live Da Vinci camera feed. The colonoscopy also gave a clear view of the blood vessels feeding into the tumors and of the variation and abnormality of the vasculature surrounding them.

Again, the total amount of time spent viewing the additional data provided by the enhanced reality interface amounted to approximately five minutes over the whole duration of the procedure. This was interpreted as an indication that the surgeon performing this colectomy also found the augmented reality useful.

7.3. Enhanced reality for a sigmomidectomy

Paralleling the results for the right colectomy, the surgeons performing the sigmoidectomies also felt that they benefited from being able to view the surroundings the organs they were working with the in operative field. Depth perception was also noted as a great benefit since this allowed the surgeons to easily evaluate the positioning of the left ureter, blood vessels, mesocolon, and pelvis, all anatomical structures important to this particular kind of surgery (Figure 5).

Total display time of the augmented reality environment was also approximately five minutes over the course of each procedure.

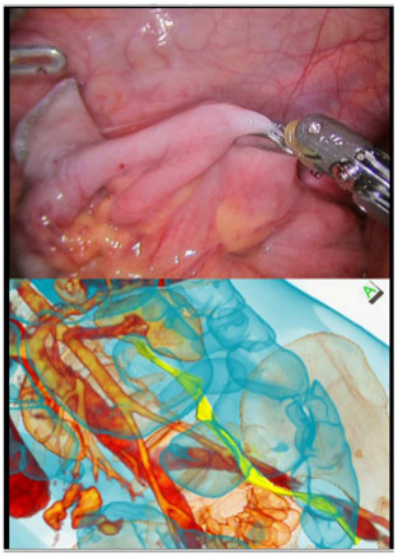

Figure 5. TilePro-activated interface during a sigmoidectomy.
Francesco Volonté '12.

8. Assessment

8.1. Positive aspects of this work

In addition to the complete and successful implementation of the enhanced reality interface, the authors also studied the benefits of the environment for three different kinds of surgical procedures. This better demonstrates that the interface is beneficial for a general target clientele of varied kinds of surgeons, rather than developed for and targeted at a surgeons of a specific procedure. This also indicates that enhanced reality could be implemented in a way that covers many kinds of procedures and does not need to be re-designed for each procedure.

The results of the clinical study were also very clear about what data that was provided by the interface was particularly useful to the surgeon for each procedure. This allows us to compare the utility for the different kinds of preoperative data that is useful for each procedure and to look for any forms of data that were useful across all types of surgeries. This gives us a better idea of what kinds of data can be incorporated into the enhanced reality environment without causing the interface to be too specific for one procedure to be used for another.

8.2. Limitations of this work

Although the augmented reality interface was successfully implemented, the clinical user study used to tests it utility and benefits was too small to generalize over a broad range of robotic surgery types, and the number of surgeons involved was too small. Indeed, the work did not even specify the total number of surgeons involved in the five procedures. Therefore, while the reviews for the enhanced reality interface were positive, a wider study must be conducted to gauge the response for a more varied group of surgeons, both in experience and in the kind of surgeries they practice.
The study also focused on procedures performed in the abdominal area. Therefore, it is uncertain whether other categories of surgeries, such as brain or reconstructive surgeries, would benefit from the same data integration features as those studied by the authors.
Regarding the authors' implementation of the interface, much was left out on the method of implementing the actual interface and the specifics of the custom OsiriX plugin. This would make it more difficult to replicate their results, should we wish to test their methods of stereoscopic image generation.

In addition, important objective details about the benefits of enhanced reality usage are also lacking. While the surgeons cite the benefits of using the interface, no data was taken or mentioned that would indicate that the mortality rate, blood loss, etc. during a procedure actually decreased due to the use of the enhanced reality interface.

9. Future work and relevance to our project

9.1. Future work for the authors

The authors mentioned that real-time image synchronization could be improved in later developments of the enhanced reality interface. They suggest that HD cameras and more powerful computers could be used to better detect and render changes in organ shape and texture that indicate a change in the organ's location or orientation.

Another suggestion was the incorporation of perioperative ultrasound to help locate predefined anatomical points on organs and other structures. Ultrasound here could be used to supplement and cross-reference the information that the surgeon receives from the live Da Vinci camera feed and the augmented reality interface's patient preoperative data.

9.2. Influence on our project

Since our project also focuses on developing an enhanced reality environment for general use on all robotic surgeries, this work gives us a guideline for what kinds and forms of data would be useful to a surgeon. This work also shows that practicing surgeons do have interest in and are open to the idea of integrating preoperative and other forms of data into the Da Vinci console that would improve the safety and likelihood of success for their procedures.

As we plan to incorporate a DICOM reader to display CT images and renderings of 3D models of organs and other anatomical structures, the positive reviews of the surgeons towards similar functions of the enhanced reality in this work show promise that our own interface development is headed in the correct direction and will incorporate functions that surgeons will find useful in the operating room.

10. Conclusions

Research on and development of augmented reality environments opens up a new and promising frontier for surgeons practicing in robotic procedures. Not only does the surgeon benefit from the physical assistance and motor fine-tuning provided by the Da Vinci robot, but he will also have direct and immediate access to patient preoperative data while at the master console. The ability to remain at the workstation and completely immersed in the procedure for its entire duration improves patient safety and the likelihood of the procedure's success. A fully developed and tested enhanced reality environment will therefore prove an invaluable tool to helping surgeons performing complex surgeries and to maintaining the safety of the patients undergoing these procedures. The crucial factor to the progress of enhanced reality is to determine which features would prove most useful to a surgeon for all or most procedures in general.