An Improved GUI and Visual Navigation of the Robo-ELF
600.446 Computer Integrated Surgery II, Spring 2012
Project Proposal

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Collaborators: Renata Smith, Dr. Jeremy Richmon

Summary and Goals:

The purpose of this project is to design and implement an improved user interface for the Robo-ELF, specifically a new robust GUI and vision-based, point-and-click motion control. The current system is undergoing review for FDA approval for clinical trials, and finishing the requirements for approval of the current system is also a major project goal.

Background:

There are approximately 25,000 annual cases of throat cancer in the United States, about 6,000 of which are fatal. Radiation and chemotherapy are common treatment methods, but surgery is often required to remove late-stage tumors from the throat. There are two options in performing this surgery, intra-airway or open throat. Intra-airway is the preferred method when possible because it is much less invasive and results in much faster recovery times. To perform intra-airway surgery, an endoscope is used to provide visualization of the larynx. Rigid endoscopes are useful because they can be positioned and held in place with a stand. However, they offer limited range of vision and cannot see at all certain areas of the sub-glottal region. This is the advantage of flexible endoscopes. They can provide a much larger range of vision than rigid endoscopes. The problem is that there is no existing mechanism to hold a flexible endoscope once it has been positioned, so another surgeon has to be present to hold and control the endoscope with two hands while the other performs the operation.

The Robotic EndoLaryngeal Flexible Scope(Robo-ELF) solves this problem. It provides a means to hold and position a flexible endoscope during surgery so the surgeon has both hands free to operate. A prototype robot was built and tested in 2011 using phantoms and human cadavers. It functioned well in testing and surgeons were pleased with the results. One complaint was that the control mechanism was unintuitive and difficult to use. This is the main motivation for this project.

Motivation:

The ultimate goal of the project started in 2011 was to produce a clinically viable system and put it through human trials. The documentation and approval process to do this is almost complete. The largest remaining task is passing FDA requirements for a clinical system. Finishing these requirements is the first goal of this project.

Looking to the future of the Robo-ELF project, a new control mechanism is sorely needed. Surgeons have expressed interest in vision-based navigation, and preliminary work has already been completed to implement point-and-click navigation of the robot. The current GUI

for the system is very limited and could provide much more useful functions to the surgeon. These interface improvements will be very valuable to future work on the project.

Technical Approach:

To complete the requirements for clinical trials, several things must be accomplished. All of the safety features, especially software, must be tested and documented for validation. This includes the software-activated emergency stop, heartbeat signal, encoder/potentiometer checking, joystick failure detection, and Galil error detection. Most of these features are already implemented, but they require more testing and documentation before being submitted for approval. Better handling of system errors should also be implemented. Errors will be split into two categories, serious and non-serious. Serious errors will require a full system restart to continue and are indicative of a serious system failure. Non-serious errors will are recoverable without restarting the system and do not present a danger to the patient. Mechanical changes to the system must also be completed to allow for easier draping and disassembly. Renata Smith and Kevin Olds are responsible for completing these changes, as well as designing a required draping system for the robot.

Once the changes and documentation are completed, we must do an FMEA risk assessment of the system and validate that all risks have been properly compensated for. Part of this compensation is a full software review which will be completed first. These system reviews will be conducted with all team members and senior members of the LCSR faculty and staff.

Vision-based navigation will be implemented using algorithms developed and tested in summer 2011 by visiting student Hongho Kim. The algorithm uses an approximate kinematic model for the flexible scope to estimate its orientation. It uses template matching to confirm it is moving in the right direction. It was developed and tested using OpenCV. Our task is to implement the same algorithm as a CISST svlFilter and integrate the results into the current control code for the robot. The new GUI will be implemented in Qt with the CISST libraries. We will meet with the surgeons to discuss the exact design and layout of the GUI and to discuss which features they would find most useful.

Deliverables:

Minimum: Complete FDA requirements for human clinical trials. This includes a full system risk analysis, documentation and testing of all safety features, a detailed user manual including setup and take down instructions, operating instructions, and explanation of software error codes.

Expected: Completion of FDA requirements. Implementation of vision-based navigation and an improved GUI. We will integrate the existing computer vision code, written using OpenCV, into the CISST libraries and with the current robot software. We will add more information to the current GUI and display it in an easy-to-use way.

Maximum: Design a brand new GUI with more interactive features. More advanced tools like displaying pre-operative data and images and feature marking on the video.

This would fully replace the current GUI instead of simply adding more data to the display.

Dependencies:

Dependency	Plan to Resolve	Resolve by
Draping Procedure	Renata is working on it	March 5
Mechanical Changes	Renata is working on it	March 12
Software Walkthrough	Schedule with lab personnel	March 26
User Manual	Renata is working on it	April 2
System Design Review and FMEA	Schedule meeting with lab personnel and Dr. Richmon	April 2
Surgeon's Desired GUI features	Meet with Dr. Richmon	March 5

Milestones:

Complete software for FDA requirements: **March 16**
Complete all other requirements for FDA approval: **April 2**
Complete Vision-Based Navigation: **March 13**
Complete new GUI: **May 4**

Management Plan:

I plan to work at least 15 hours per week on the project. We will reassess deliverables and timeline after the completion of each milestone, adjusting our schedule as necessary.

Meeting schedule:

Weekly meetings with Kevin Olds, Jon Kriss and Renata Smith
Bi-weekly meetings with Dr. Taylor
Monthly meetings with Dr. Richmon

Timeline:

Deliverables	24-Feb	2-Mar	9-Mar	16-Mar	23-Mar	2-Apr	6-Apr	13-Apr	20-Apr	27-Apr	4-May	10-May
Implement and test safety features												
Improve Error Logging and Handling												
Software Documentation												
Software Risk Analysis												
Software Walkthrough and Review				Software for FDA approval finished								
FMEA						Ready for full design review						
User Manual												
Vision-based navigation								Vision-based nav finished				
svlFilter for vision code												
Integrate vision into control code												
New intra-operative GUI											New GUI finished	
Design for new GUI												
Visual representation of robot pose												
Full display of robot status												
Final Report												Course Complete

In progress
Complete
Major Milestone

Reading List:

Olds, K., Hillel, A. T., Cha, E., Curry, M., Akst, L. M., Taylor, R. H. and Richmon, J. D. (2011), *Robotic endolaryngeal flexible (Robo-ELF) scope: A preclinical feasibility study*. The Laryngoscope, 121: 2371–2374

Reilink, R.; Stramigioli, S.; Misra, S.; , "Image-based flexible endoscope steering," *Intelligent Robots and Systems (IROS), 2010 IEEE/RSJ International Conference on , vol., no., pp.2339-2344, 18-22 Oct. 2010*

McLeod, I.K., Mair, E.A., Melder, P.C. Potential applications of the da Vinci minimally invasive surgical robotic system in otolaryngology. *Ear Nose Throat J 84, 483-487, 2005.*

Buckingham, R.O.; Graham, A.C.; , "Computer controlled redundant endoscopy," *Systems, Man, and Cybernetics, 1996., IEEE International Conference on , vol.3, no., pp.1779-1783 vol.3, 14-17 Oct 1996*