Robotically Augmented Flexible Endoscope

Project Proposal

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Sponsor: Dr. Jeremy Richmon

Stated Topic and Goal

The main goal of this project is to design, build and test a clinical quality prototype robotic throat tumor ablation system. The system will drive a flexible laryngoscope to be controlled intra-operatively in order to produce a robotically controlled distal-chip flexible laryngoscope which allows for all movement to be controlled by a 3D mouse. This device should allow for the advancement of a fiber optic laser through the working port of the laryngoscope, giving access to the tissue areas deep in the aero digestive system. This will provide a high-resolution, magnified image of the tissue as well as provide fine micromanipulation of the laryngoscope tip and the laser allowing for movement around corners and other complex three dimensional anatomy.

Relevance and Importance

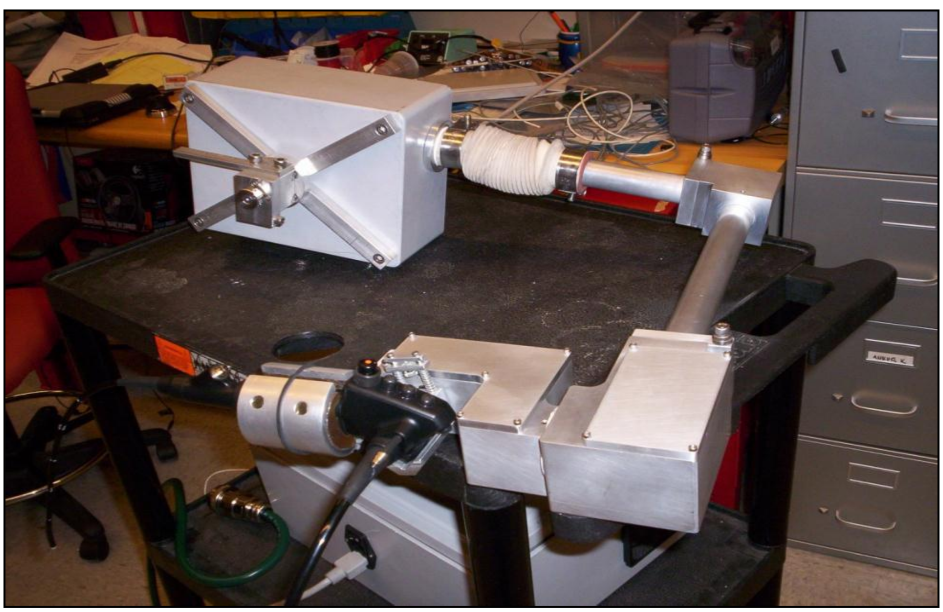
There are approximately 25,000 new cases of throat cancer in the US each year, resulting in approximately 6,000 deaths per year. Radiation and chemotherapy can have many undesirable side effects, especially in an area as sensitive as the throat. Thus, surgical approaches are often used to treat throat cancer. There are currently two main surgical approaches. The first operates by making incisions in the patient's neck. This method has a higher risk of infections, scarring, complications and a longer recovery time. The other approach operates from inside the airway using an endoscope and specialized surgical tools including a cutting laser. This is a much less risky surgery that allows for a shorter recovery time. However, with the use of an endoscope there are limitations in visibility and the space of equipment. Currently, to perform an intra-operative surgery at least four hands are needed as operation of the endoscope requires two hands and the laser and another working tool require one each. The endoscope is also difficult to maneuver and often destabilizes if the hands controlling it are removed. This leads to the necessity for several people to crowd around the patient and a clutter of the operating room. Another limitation in the past has been the inability of the laser to navigate around “bends” in the tissue. An improved intra-airway surgery using a robotic device to control the endoscope and laser would allow for the reduction of clutter, better feasibility and more accurate control of the equipment. New endoscopes with working ports allow for a fiber optic laser to be used to navigate bends in the tissue for greater accuracy and safety. An intra-airway surgery can also be done potentially as an outpatient procedure reducing costs for anesthesia and hospital stays.

Technical Summary of Approach

3 degrees of freedom are necessary for optimal robotic control of the flexible laryngoscope; one to translate the endoscope in and out of the airway, one to rotate the endoscope along its axis through the airway, and one to control the tip of the endoscope. First, the individual mechanical parts of the robot must be manufactured or ordered. These parts need to hold up under corrosive materials and be waterproof in order to survive in the operating room and remain sterile. Other mechanical constraints the robot faces includes: easy to clean, water resistant, absent of allergens, cannot contain toxic materials, well grounded, lightweight, durable, able to be shutoff in cases of emergencies (either from problems in surgery or hardware).

The scope being used with the robot is a VNL-1570STK which is equipped with a 2.0 mm channel whose working port allows navigation around the "bends" in tissue. This endoscope also should allow for enough space for the surgeon to use an additional tool in his or her free hand. The scope will be attached to 3 motors which allow for the 3 degrees of freedom previously mentioned. These motors will allow for the movement of the endoscope tip, the turning of the endoscope as well as the movement of the endoscope in and out? The motors will have built in encoders to take digital position changes? as well as a set of potentiometers to measure the joints since absolute measurement is necessary. This second set of data will also allow the robot to check the measurements taken by the encoders as a safety mechanism in case of failure of the encoders. The combined digital and analog systems make overall system more robust due to their different failure points.

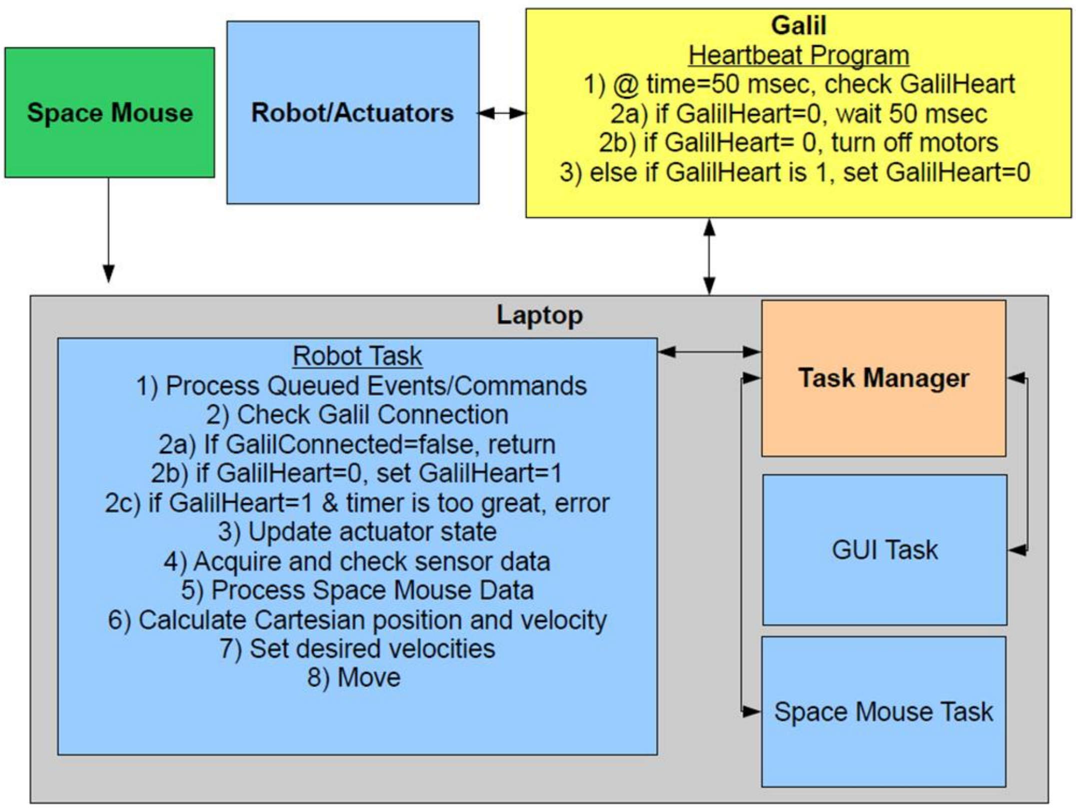
The motors will all be controlled using a Galil Motion Controller. The Galil Motion Controller will be enclosed in a NEMA enclosure (or box) along with a power supply. The Galil controller runs on 12 V and contains several analog and encoder inputs for each channel. The Galil controller will also use an ethernet interface to run to the Mil-spec laptop. The laptop will be drop resistant, spill resistant, high performance and long battery life. The laptop will use preexisting code from the CISST libraries in order to build an interface for the Galil Controller and the overall robot. This interface should also include compatibility with the CISST library software for the 3D space mouse.

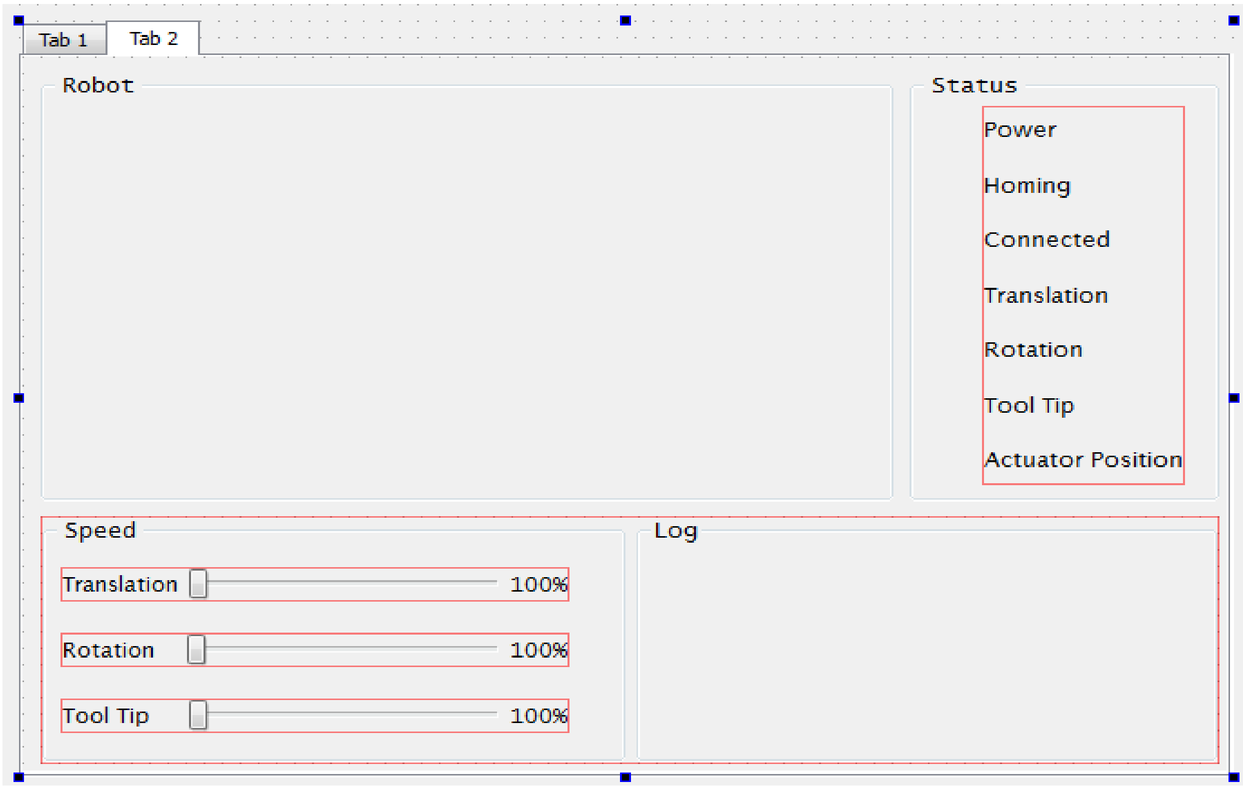


Currently, we are using a 3D space mouse to interface with the surgeon. However, we hope to replace this device with another controller with 3 axes of motion that is more durable and sensitive to smaller movements. We plan to design and build our own. We plan to use USB protocol. This requires that a new wrapper be created to be used with the CISST libraries. If a suitable input device is found, a significant amount of work will still need to be done in order to make it compatible with the CISST libraries. We plan to follow a similar approach in code to that which exists for the Space Mouse currently.

The user interface will be created using QT. It should allow the surgeon to vary certain parameters of the robot including the range of velocities for each joint. It should also allow for mouse control of each of the joints. We hope to add a visualization debugging feature which should show us where each axis should be. It should also include a general message log and error lights which will alert the surgeon to various errors that may be occurring.

The system should also include various safety features in both hardware and software. We plan to use redundant sensing via linear potentiometers to detect possible position errors in the encoders or motion controller. Limit switches will stop any joint from being stressed to a dangerous point. In software, a “heartbeat” feature will be implement using the Galil Motion Controller and the laptop. The two systems will constantly send a “heartbeat” ping back and forth. If one system has not heard the heartbeat to send back within a certain time period, currently set at 50 µs, the entire system will cut powers to all motors.





Deliverables

Minimum

- Functioning system capable of performing mock operations with phantoms/cadavers
  - Use of a robotized endoscope with:
    - Single hand operation for laser and scope, leaving the other hand free to use tissue manipulators
    - Built-in working channel for cutting laser
    - Precision movement
    - Laser and scope remain stationary when hands removed
  - Redundant Sensing
  - Proper grounding
  - Easy to clean
  - Emergency shutoffs and release
  - Small and Lightweight
  - "Operating-room-proof"
  - Built in software safety limits

Expected

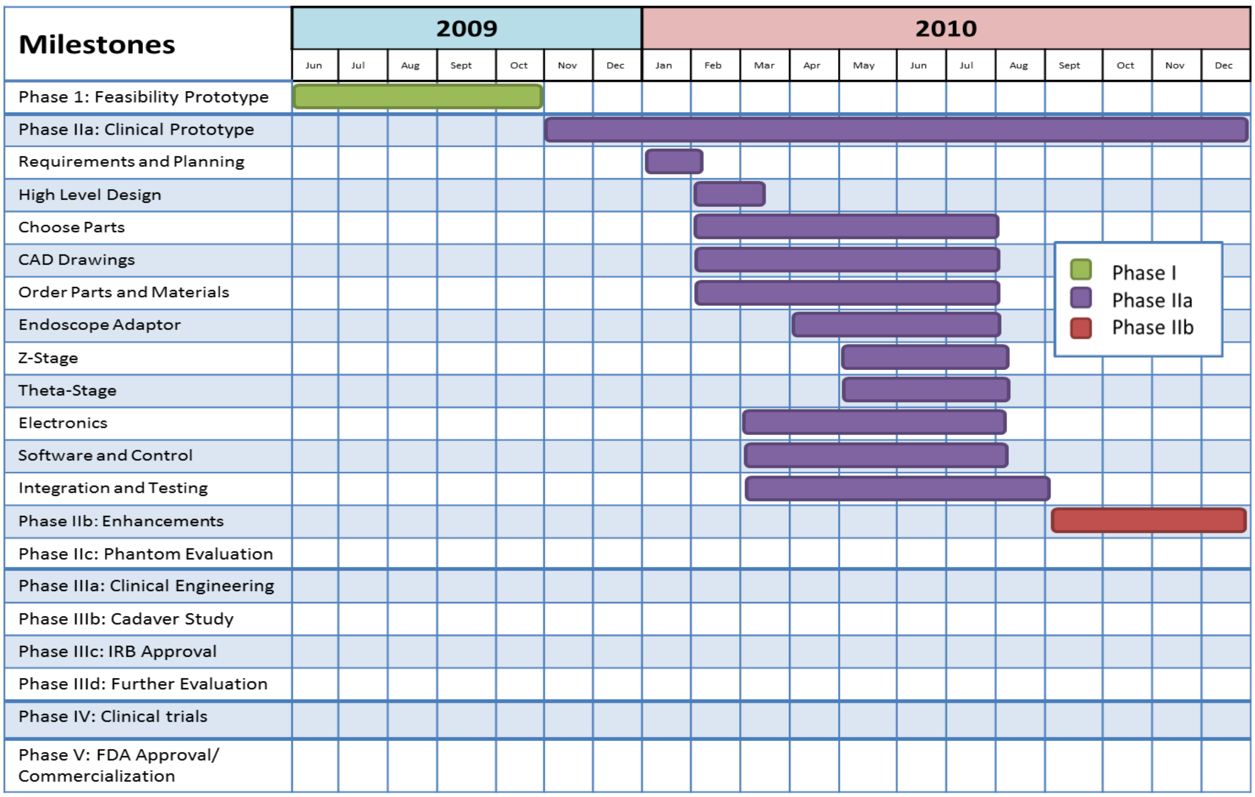
- Minimum plus extensive phantom/cadaver experiments demonstrating functionality of system
- Design and construction of new input device
- User Interface

- Control of each axis of motion
- Error messages and warning lights
- Variable speed control for each joint

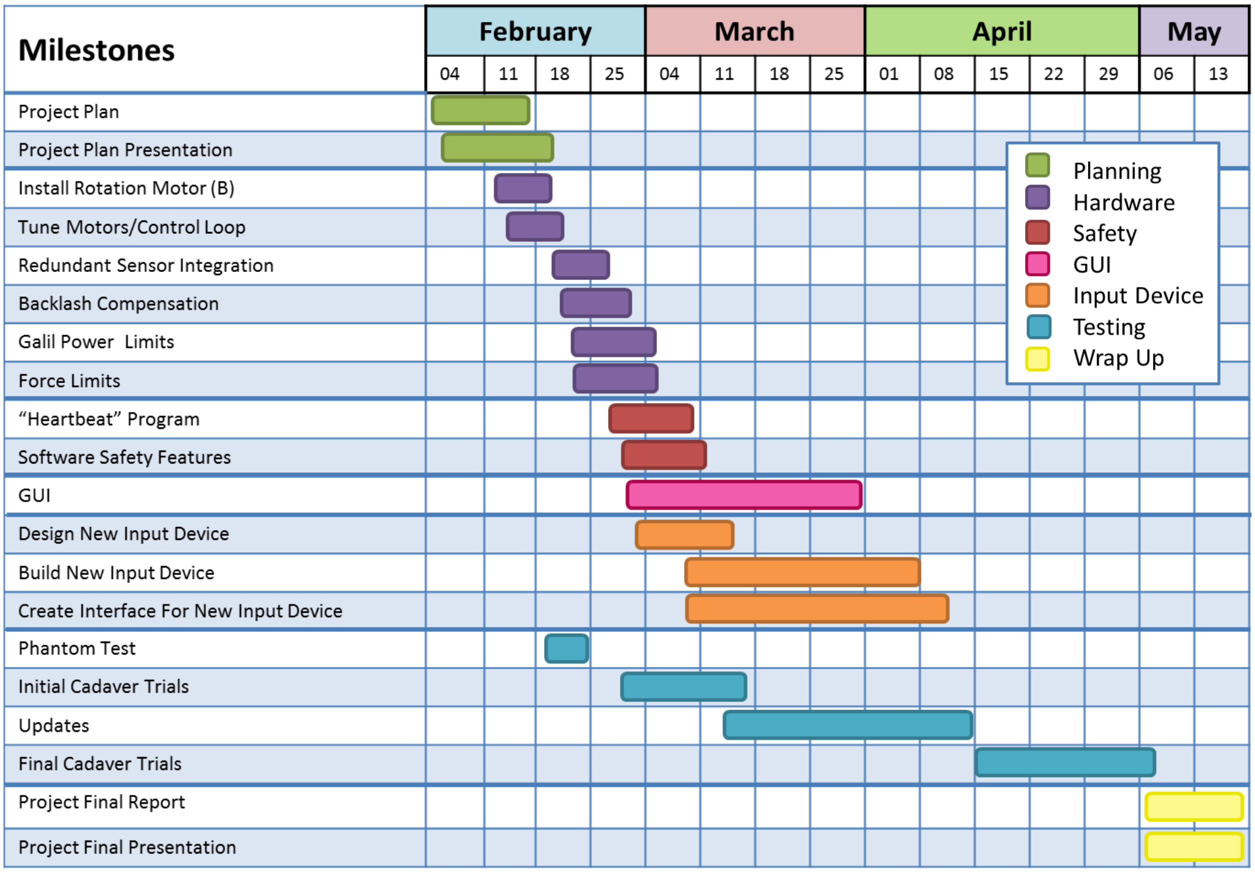
<u>Maximum</u>

- User interface that gives visualization features

Previous Work



Timeline



Dependencies

Dependency	Plan to Resolve	Resolve By	Affects
Cadavers Required	Have Surgeons Order	Resolved	Expected
Surgeon Feedback	Schedule Meeting	Resolved	Minimum
New Space Mouse	Order new mouse	Resolved	Minimum
New Translation Motor	Order new motor	Resolved	Maximum
Mechanical Work	Have Kevin finish	February 16	Expected
Funding	Submit budget proposal	Resolved	Maximum
New Input Device	Find an alternative or build alternative	April 1	Maximum
Electronics Equipment	Ask Dr. Taylor	March 9	Expected
QT toolkit/RobotGUI task	Talk to students in Lab	March 1	Maximum

Management Plan

- Daily meetings with Kevin Olds
- Weekly meetings with Dr. Taylor and Kevin Olds
- Monthly meetings with Dr. Richmon and Kevin Olds

Budget

Items	Budget Allocation
Scope	$22,000
Scope interrogator	$2,000
Hardware	$12,000
• Theta-stage	$2,000
• Z-stage	$2,000
• Motor Controller	$2,000
• Motors/Encoders	$1,500
• Misc. Shop Materials	$500
• Computer/accessories	$1,000
• Machinist Fees	$1,000
• Phantom Costs	$500
Enhancements	$2,900
Phantom Study	$925
Clinical Engineering	$2,875
Cadaver Study	$11,875
Total	**$54,575**

Reading List

- 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

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- 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
- Parmar, Amit, David G. Grant, and Peter Loizou. "Robotic Surgery in Ear Nose and Throat." *OTO-RHINO-LARYNGOLOGY* 267.4 (2009): 625-33. Print.
- Dario, Paolo. Endoscopic Robot. Scuola Superiore Di Studi Universitari E Di Perfezionamento S. Anna, assignee. Patent 2767705. 21 Oct. 1997. Print.