Robotic Endoscopic Tumor Ablation System

Kevin Olds, Liz Cha
Mentors: Dr. Russell Taylor
Sponsor: Dr. Jeremy Richmond
Motivation

• There are approximately 25,000 new cases of throat cancer every year in the US, resulting in approximately 6,000 deaths per year

• Radiation and chemotherapy have many undesirable side effects, especially in a sensitive and critical area like the throat

• Surgical approaches are often used to treat throat cancer
Surgical Techniques

- Types of surgical techniques in throat surgery:
  - Through incisions in the patient’s neck
  - Inside the airway using an endoscope and specialized surgical tools including a cutting laser
Pros and Cons of Intra-Airway

• Advantages of Intra-Airway
  – Less risk of infection
  – Less scarring
  – Smaller risk of complications (damaged vocal cord nerves, etc.)
  – Faster recovery time

• Disadvantages of Intra-Airway
  – Limited visibility
  – Limited working room
Current Intra-Airway Surgery at JHMI

• Minimum of 4 hands needed:
  – Laser and endoscope are separate instruments
  – Endoscope needs two hands to operate
  – 3rd grabbing instrument is needed
• Laser is rigid and cannot bend around corners
• Scope does not remain stationary when hands removed and is difficult to control accurately
• Result: working environment is crowded and awkward and visibility is poor
Problem

• Current methods for throat tumor removal require multiple surgeons, risky/expensive surgeries with general anesthesia, and unnecessarily long hospital stays
• Other devices are not specialized, too expensive or don’t have the functionality for a full system.
Goal

Design, build, and test a clinical quality prototype robotic throat tumor ablation system to aid in performing minimally invasive intra-airway surgery done potentially as an outpatient procedure under local or weak general anesthesia.

– Reduce number of hands needed
– Control all motion of endoscope
– Allow for use of one hand to control system leaving surgeon free to hold tool in other
– Have scope remain stationary with no hands
Solution

• Use a robotized endoscope with:
  – Single hand operation for laser/scope, leaving the other hand to use tissue manipulators
  – Built-in working channel for cutting laser
  – Precision movement
  – Laser and scope remain stationary when hands removed
  – Use pre-existing clinical endoscope and laser to minimize cost
Our Approach

- Design and build a 3 axis robotic assistance device
- Uses a laptop for surgeon to control system
Constraints and Design Issues

- Resistant to long term exposure to hospital grade cleaning agents
- Cannot contain any allergens or toxic materials
- Submersion proof
- Well grounded
- Should not have a lot of mass over the patient
- As few visible moving parts as possible
- Corrosion resistant seals
- All exposed metal parts must be stainless steel, aluminum, or plastic
- Robot must be able to resist bumps and minor abrasions
Deliverables

• Minimum
  – Functioning system capable of performing mock operations with phantoms

• Expected
  – System capable of performing extensive cadaver experiments demonstrating functionality of system
  – User interface able to control and adjust system
  – Extensive documentation
  – System able to pass clinical engineering standards

• Maximum
  – Image Processing and new input device
Prototype I
Hardware

- Three coreless brushed servo motors with planetary gearheads
- Integrated magnetic encoders
- Linear potentiometers for redundant sensing
- Galil Motion Controller (DMC-4030) with 20 W linear amplifiers
- Waterproof exterior
- +/-12 V isolated power supply
Current Status

• Initial proof of concept prototype using LARS completed
• Clinical prototype 1.0 completed
• This presentation covers the upgrades to transition Clinical prototype 1.0 to clinical prototype 2.0
Upgrades

• Rotation stage motor/gearhead
  – More torque
  – Better control
  – Smoother, more regular motion

• Scope handle motor upgraded to fit in enclosure with scope handle manipulator
  – Eliminates mechanical cable
  – Reduces backlash
  – Frees up room for rotation stage motor upgrade
Upgrades (2)

• Bicycle cable to low-stretch aircraft-grade rubber coated cable
• Use handles to adjust robot instead of wrench
• Robust locking electrical connectors
• Screw driven one-site-adjustment removable cable tensioner
• Adjustable latch for holding scope
Prototype 2.0
Galil Box
Scope Box
Summary

• Parts in final robot
  – Parts machined by me: 70+
  – Parts machined by Rich: 7
• Total parts machined
  – By me: 100+
  – By Rich: 9
• Total solder connections: 300+
• Robot tested to be operable under water
• Robot tested on human cadavers and shown to improve surgical performance
• Unplug-carry-plug-play portability
• Easily accepts other comparable scopes
Future Work (Hardware)

• Arrange informal clinical engineering evaluation in preparation for IRB application
• Fine-tune pot feedback and possibly add further filtering
• Develop detailed testing and failure detection plan
• Design and build support arm for robot
• Design and build tower containing robot electronics, scope interrogator, video processing PC, and mount for robot
Lessons Learned

• Mechanical cables are a huge pain without a good tensioner (and a moderate pain with one)
• Gearheads have more backlash than you would like
• Using one big electrical cable is annoying for fabrication, but great to work with and well worth the investment
• Aiming for a more robust initial design with upgrades in mind is a good idea for a prototype
  – Don’t waste time repairing trivial problems
  – Transport and setup are much easier
Software

• Utilizes CISST libraries
• Controls each axis of motion separately
• Contains software safety features and limits
• GUI
  – alternative way to move robot
  – adjust speed and other variables
  – visualization/debug feature
Software

Task Manager

User Interface

CISST Galil Wrapper/Task

Galil Controller

Space Mouse/Input Device

3D mouse Task/Wrapper

Potentiometer (Analog)

Servo Motor

Integrated Encoder (Digital)

Actuator

Background Goal Approach Conclusion
Main Program/ Functions

- Start up
- Configure
- Home
- Run

- Robot Run/Move
- Safety Features
- GUI
GUI

[Image of a GUI interface with tabs for Robot and Status, showing options like Power, Homing, Connected, Translation, Rotation, Tool Tip, and Actuator Position. Below, a Log section with entries for Translation, Rotation, and Tool Tip, all set to 100%.]
Testing Plan

- Clinical Engineering Standards (waterproof, grounded, chemical resistant, etc.)
- Phantom Evaluation
- Initial Cadaver Study
- Final Cadaver Study
Initial Cadaver Trials
## Dependencies

<table>
<thead>
<tr>
<th>Dependency</th>
<th>Plan to Resolve</th>
<th>Resolve By</th>
<th>Affects</th>
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<tbody>
<tr>
<td>Cadavers Required</td>
<td>Have Surgeons Order</td>
<td>Resolved</td>
<td>Expected</td>
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<tr>
<td>Surgeon Feedback</td>
<td>Schedule Meeting</td>
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<td>Minimum</td>
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<tr>
<td>New Space Mouse</td>
<td>Order new mouse</td>
<td>Resolved</td>
<td>Minimum</td>
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<td>New Translation Motor</td>
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<td>Mechanical Work</td>
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<tr>
<td>Funding</td>
<td>Submit budget proposal</td>
<td>Resolved</td>
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<tr>
<td>New Input Device</td>
<td>Find an alternative or build alternative</td>
<td>April 1</td>
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<tr>
<td>Electronics Equipment</td>
<td>Ask Dr. Taylor</td>
<td>March 9</td>
<td>Expected</td>
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<tr>
<td>QT toolkit/RobotGUI task</td>
<td>Talk to students in Lab</td>
<td>March 1</td>
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## Timeline and Milestones

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<th>March</th>
<th>April</th>
<th>May</th>
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<td>Project Plan Presentation</td>
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<tr>
<td>Install Rotation Motor (B)</td>
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<td>Tune Motors/Control Loop</td>
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<td>Redundant Sensor Integration</td>
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<td>Backlash Compensation</td>
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<td>Galil Power Limits</td>
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<td>Force Limits</td>
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<td>“Heartbeat” Program</td>
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<td>Software Safety Features</td>
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<td>Documentation</td>
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<tr>
<td>Find New Input Device</td>
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<td>Create Interface For New Input Device</td>
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<td>Initial Cadaver Trials</td>
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<td>Updates</td>
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<td>Project Final Presentation</td>
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**Legend:**
- **Planning**
- **Hardware**
- **Safety**
- **GUI/Documentation**
- **Input Device**
- **Testing**
- **Wrap Up**
Management Plan

• 25 hours per week on project (Liz)
• 10 hours per week on project (Kevin)
• Reassess deliverables at each milestone
• Meeting Schedule
  – Weekly meeting with Dr. Taylor
  – Monthly meeting with Dr. Richmond
## Budget

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<td>- Motor Controller</td>
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Questions?