Improving The Transparency Of The Galen Robot

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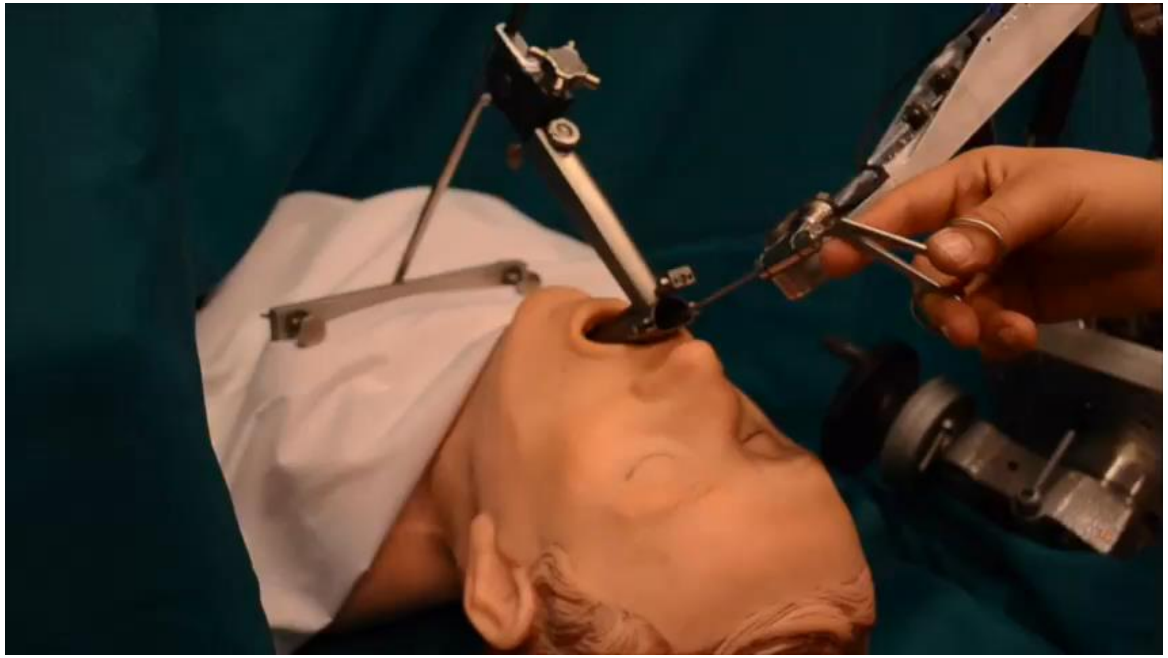
Background

- The Galen Robot (Mk-2) is a prototype 5-DoF Delta robot intended for ear nose and throat surgical use.
- 6-axis F/T sensor mounted between the robot and the end effector (wrist) for hand-over-hand control mode.
- Steady platform, elimination of hand tremors and enforcement hard or soft limits.
- The tool is typically, but not limited to, a surgical drill intended for cutting bone.

Project Goal

The goal of this project is to improve the transparency of the Galen hand-over-hand surgical robot i.e. to make the tool feel ‘weightless’ in the hands of the operator. Currently, while using the hand-over-hand control mode on the Galen Mk2, the tool feels reasonably weightless but this project aims to improve this ‘feel’ even further and make the robot more responsive to operator input.

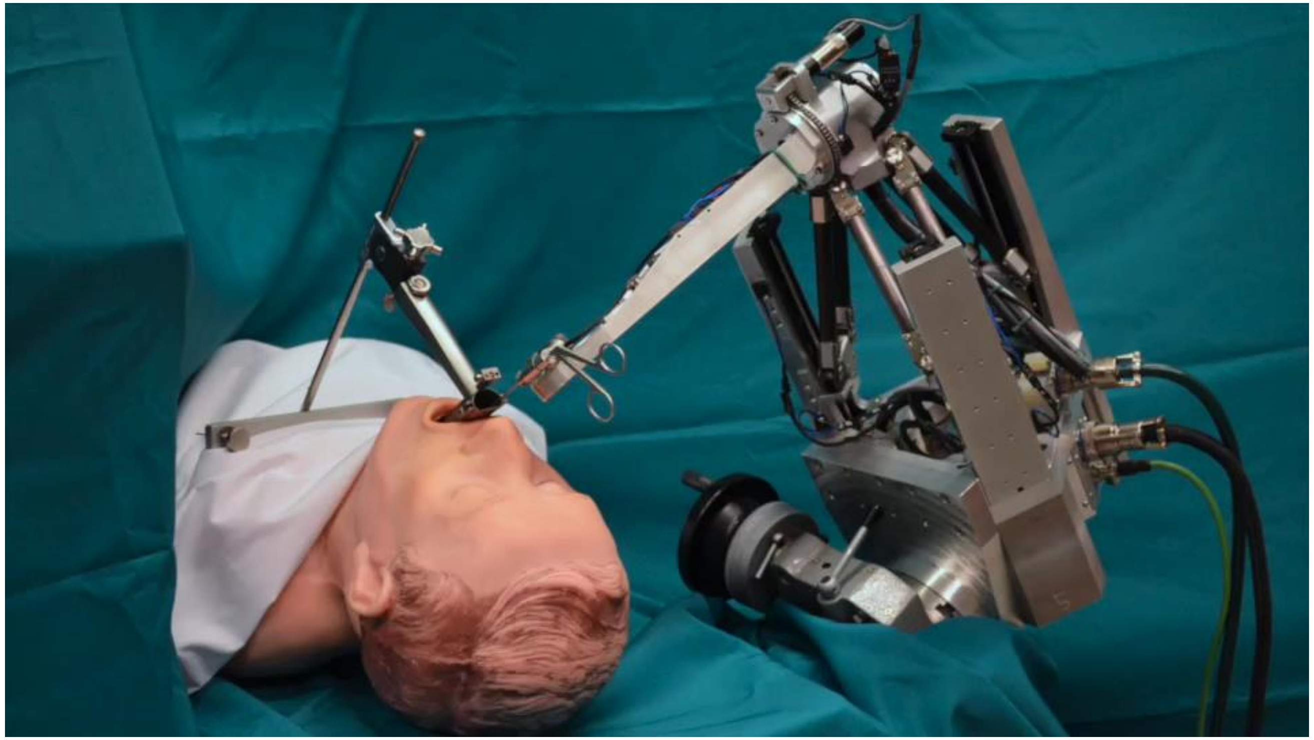


Hand-over-hand operation of REMS (Galen Mk0)

Video Credit:
[21] L. Akst, K. Olds, M. Balicki, P. Chalasani, and R. Taylor, "Robotic Microlaryngeal Phonosurgery: Testing of a “Steady-Hand Platform", Laryngoscope, vol. 128-, pp. 126-132, Jan., 2018. May 12 10.1002/lary.26621, PMID: 28498632

Relevance

As demonstrated in previous literature, the Galen robot has many applications in microsurgery where it can be used to overcome challenges such as reduced visibility, limited working space near sensitive anatomy, poor sensory feedback and difficulty of manipulation.



Video Credit:

[10] A. S. Ding, S. A. Capostagno, C. R. Razavi, Z. Li, R. H. Taylor, J. P. Carey, and F. X. Creighton, "Volumetric Accuracy Analysis of Virtual Safety Barriers for Cooperative-Control Robotic Mastoidectomy", *Otology & Neurotology,* vol. 42- 10, pp. e1513-1517, 2021.

Overall Status

- Ambitious initial project plan and deliverables
- Learning experience
- Project delayed by two weeks and missed milestone
- Dropped some maximum deliverables
- Minor hardware issues with robot

Updated Deliverables

- Minimum:
  1. Code with corrected control loop timing
  2. Documentation describing changes
- Expected:
  1. Tuned admittance gain at maximum stable limit
  2. Experimental data and operator testing result analytics
- Maximum:
  1. Code with adaptive gains control loop implemented

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Updated Milestones

Date	Milestone	Status
Mar 15th	Established transparency metrics Collected data to establish baseline	Complete
Mar 27th	Experiments show improved transparency by 20%	Missed
April 14th	Completed testing of corrected control loop	Pending
April 26th	Adaptive gains implemented	Pending

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Updated Timeline

Activity - Week	1-2	3-4	5	6	7	8	9	10	11	12	13	14	15	16+
Project definition & preparation														
Literature review, plan proposal, presentation														
Increasing & tuning admittance gains + testing														
Spring break														
Code cleanup & control loop timing														
Adaptive gains implementation														
Documentation														
~~Sensor Data Filtering~~														
~~Improved dynamic model~~														
~~Tool-tissue force inclusion~~														
Final posters & report														
Continued work, missed goals														

Updated Dependencies

Dependency	Contact	Status	Plan of action	Expected date	Consequence if not fulfilled	Contingency
Functioning robot, PC	Dr. Taylor	Fulfilled*	-	-	Project cannot continue	New project to fix robot/use Mk1
Access to Mock OR, code repos, documentation	Dr. Taylor, Florin	Fulfilled	Contacted Florin for code access	Mar 4th	Prevented from code access at home	Access code and documentation from Mock OR
Functioning tool for robot	Anna, Adnan	Fulfilled	-	-	None	Will use different tool
Availability of robot	Anna	Ongoing	Book time on robot in advance	-	Restricted to WFH, limited testing & feedback	Use sharepoint to schedule time
Availability of mentors and surgeons for testing	Dr. Galaiya, Adnan	Ongoing	Schedule time in advance	-	Unable to get constructive feedback	Test robot with mentors, peers

*Some minor intermittent hardware issues with the Galen robot; usually resolved within 36h

Technical Approach – Establishing Metrics

1. Magnitude of force vector from F/T sensor was recorded with different gains
2. Robot was moved by me to match the square shape as shown 3 times
3. Tried to maintain constant velocity throughout.
4. May not be a reliable method to test improvement in transparency.

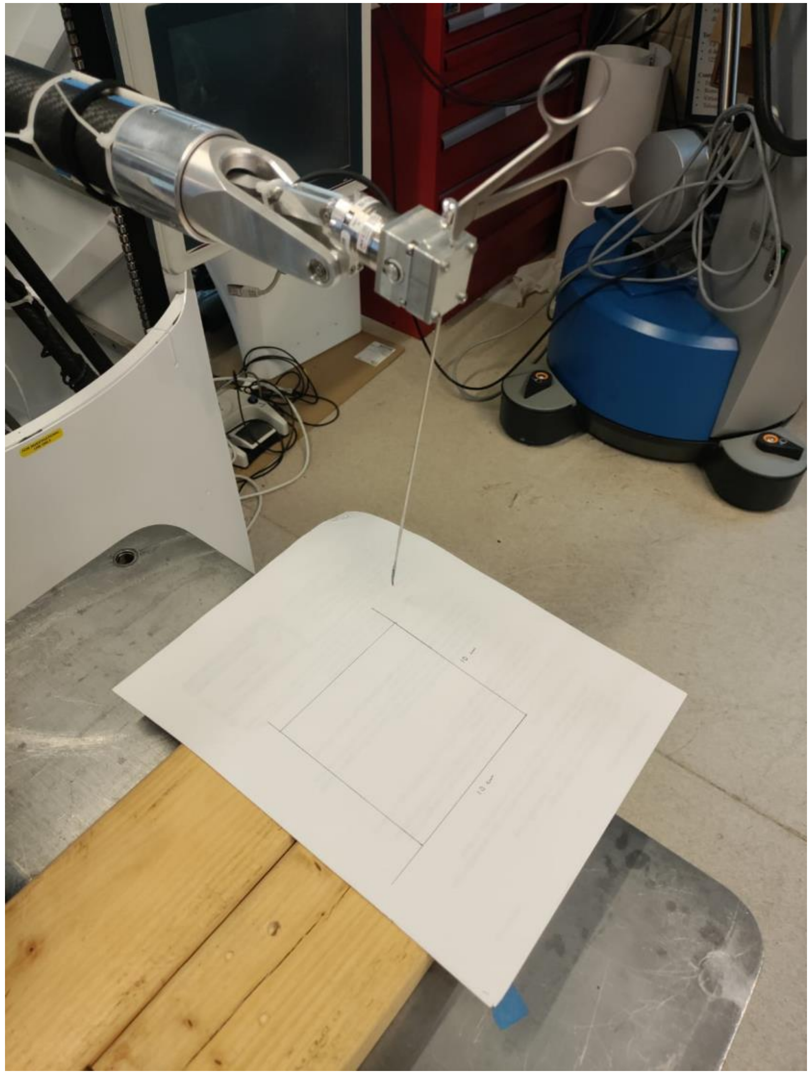
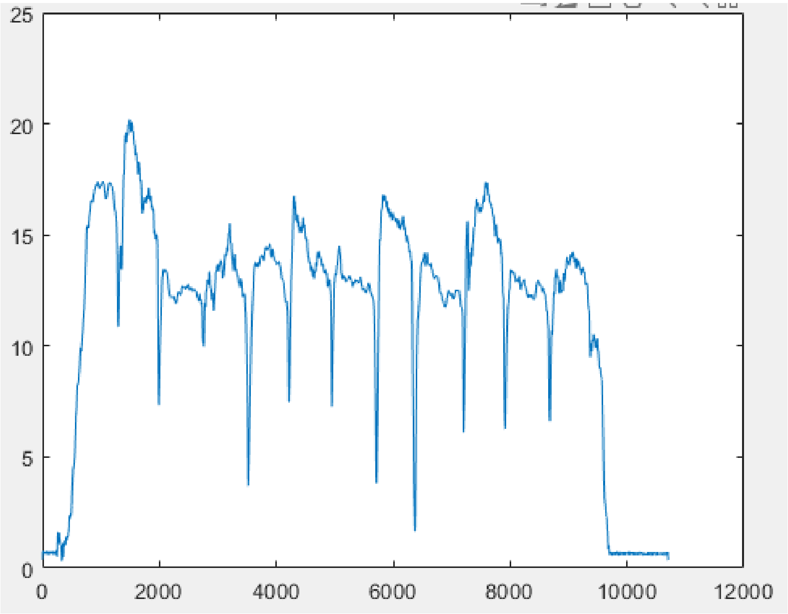
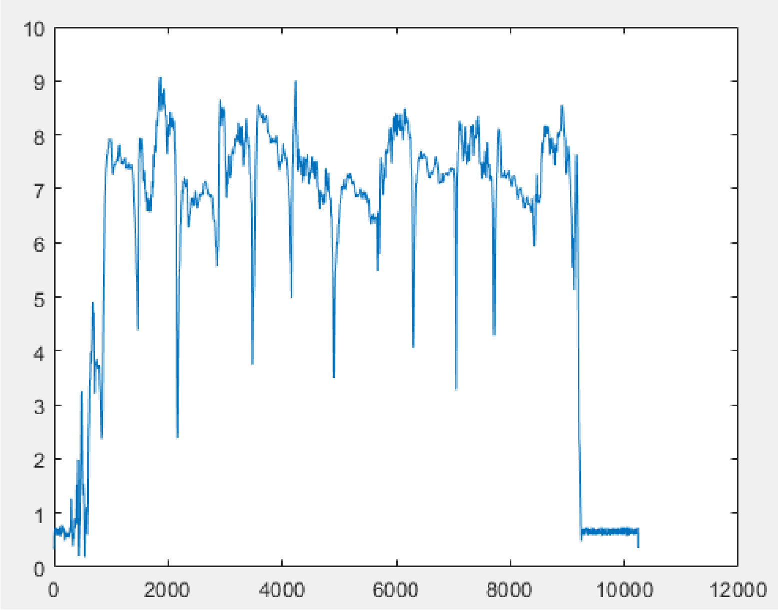
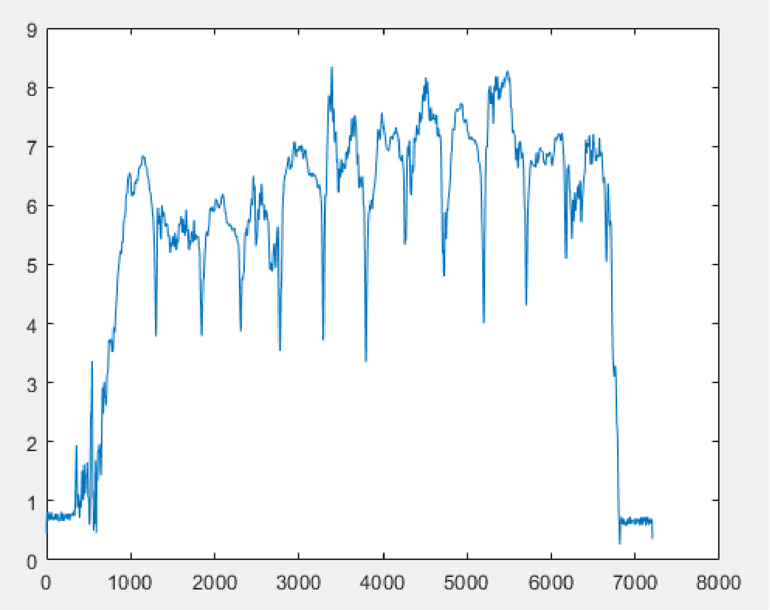


Image: L. Akst, K. Olds, M. Balicki, P. Chalasani, and R. Taylor, "Robotic Microlaryngeal Phonosurgery: Testing of a "Steady-Hand Platform", Laryngoscope, vol. 128-, pp. 126-132, Jan., 2018. May 12

Sensor force(N) vs gain







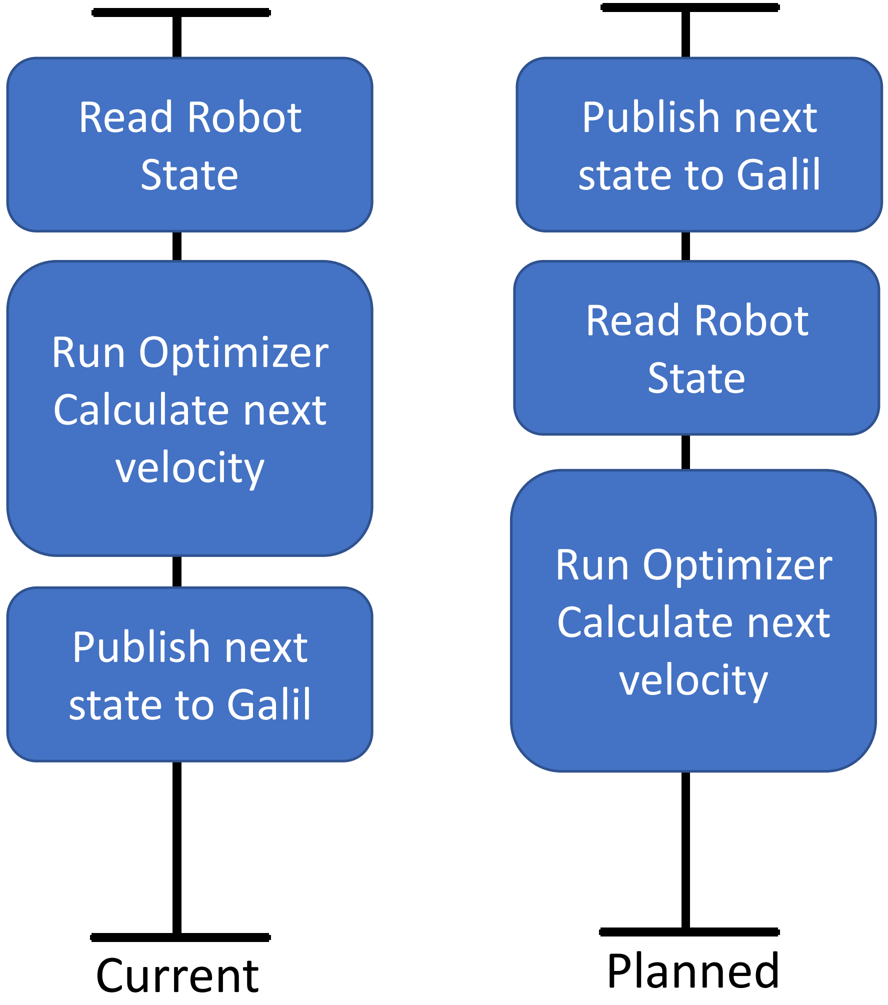
Mean:13.36
Gain=1

Mean:7.13
Gain=2(default)

Mean:6.27
Gain=4

Technical Approach – Control Loop Timing

1. Velocity commands sent from mid-level (admittance) controller to low-level (Galil) controller.
2. 200Hz refresh rate of the PC, maximum 1000Hz capable Galil.
3. Velocity commands sent at irregular intervals may cause inaccuracies.
4. To correct, commands will be sent at the beginning of control loop.
5. Currently work in progress.



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Questions

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