Force-Sensing Forceps for Cochlear Implant Surgery

and

Hand Control Interface for Galen Tool Holder

Plan Proposal

EN 601.656 Advanced Computer-Integrated Surgery (CIS II)

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Project Topic and Goals:

A cochlear implant is a small electronic device that electrically stimulates the cochlear nerve (nerve for hearing). The implant has external and internal parts. The external part sits behind the ear. It picks up sounds with a microphone. It then processes the sound and transmits it to the internal part of the implant. However, currently, there are no established methods for guidance, monitoring, or feedback to the surgeon and the implant insertion process is entirely dependent on surgeon dexterity. [2]. Studies show that overall 17.6% trauma rate which implies that CI (Cochlear Implantation) insertion could be improved with more accurate and consistent electrode insertion.[3]

With regards to robot-assisted surgery (RAS), studies show patient outcomes are associated, in part, with the number of RAS procedures a surgeon performs translates a smooth operation with [4]:

- Decreased operation time
- Fewer chances of hemorrhage
- More flexibility in procedures
- 3-D and magnified image of the surgical site
- Greater precision due to elimination of surgeon's hand tremor

The goal of the project is to design a prototype for testing the force-sensing forceps that can measure force, thereby enabling successful and safe insertion procedures which will eventually reduce the trauma rates.

Also, the Hand control interface will change the gains of the Galen robotic arms which will smoothen the operation of the robot helping surgeons operate the robot according to their variability.

The goal of the semester is

1. To design and develop a fully working prototype and testing
2. Calibration and Testing of the new Force/Torque sensor
3. Experimental methods to create calibration procedures to validate the sensor data concerning ground truth.
4. To design the grip and placement of the buttons (switches) based on ergonomic feedback from the surgeon.
5. To interface the buttons with the controller externally to change the gain of the controller.

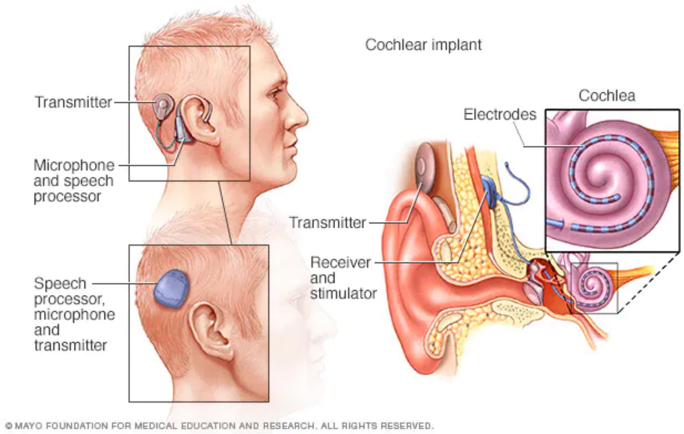

Figure 1. Cochlear implant with electrode array inside the cochlea [1]

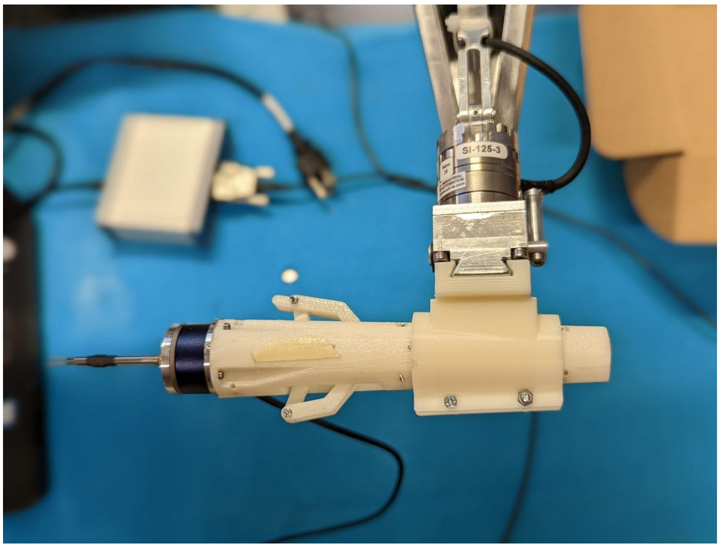

Figure 2. Force Sensing forceps embedded with the sensor

Figure 3. Galen Robot with attached tool

Team Members

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Graduate Student, Laboratory of Computational Sensing and Robotics, Johns Hopkins University

Mentors

- Primary Mentor: Anna Goodridge (anna.goodridge@jhu.edu)

  Assistant Research Mechanical Engineer, LCSR

- Principal Investigator: Prof. Russell Taylor (rht@jhu.edu)

  John C. Malone Professor, Department of Computer Science

  Director, LCSR

- Surgeon Mentor: Dr. Deepa Galaiya (gdeepa1@jhmi.edu)

  Assistant Professor of Otolaryngology-Head and Neck Surgery

- Secondary Mentor: Justin Kim (iordachita@jhu.edu)

  Department of Mechanical Engineering, Johns Hopkins University

Relevance/Importance:

The Force sensing forceps will control the minimal force required in the cochlear invasive implant surgeries which will prevent damaging the ear, cochlea, eardrums, etc. by the surgeons. The design will also make the cochlear implant process easier by "Gripping electrode".
Also, the Hand control of the robot will eliminate the foot padel which is hard to coordinate (control) during the surgical procedures and easier to smoothen the operation of the robot depending upon the application.

Technical Summary:

- The forceps are attached to a Force/Torque sensor " **WITTENSTEIN™ Hex21 6-Axis Force/Torque Sensor** " which collects data in real-time.
- Generated data is validated through many experimental methods such as calculating spring constants of Jaws and the springs using the Force equation,

$$F = -k \cdot x \text{ (displacement of the spring/jaws) in Newtons}$$

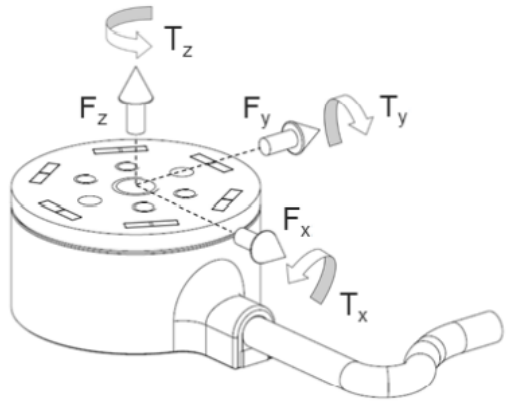

Figure 6.2: Coordinate axes definition of HEX 21 F/T sensor [5]

Data collection

- The DAQ (Data Acquisition interface) used is "**MEASUREMENT COMPUTING™ USB-202**" interfaced with switches used to change gains.

Gain Change

<u>Dependencies and Plan:</u>

Dependencies	**Plan**
Force/Torque sensor false readings	Tool calibration
Sensor isolation	Design 3-D casing to prevent it from generating false data
Hand-calibration	Mounting over the robot to filter hand tremors
DAQ interface ROS package	Find ROS package else, change the DAQ to the one having ROS package

Deliverables:

	Deliverables	Dates
Minimum	Improved design of the Forceps	1-March
Minimum	Complete Integration of Prototype	8-March
Minimum	Interface of the DAQ with controller	15-March
Expected	Sensor data collection and validation	29-March
Expected	Calculating actual forces using the Jaw and the spring load	12-April
Expected	Validation of the ground truth data	26-April
Expected	Calibration of the sensor and jig	3-May
Maximum	More tests under different conditions	TBD
Maximum	Variables gain of the controller in real-time	TBD
Maximum	Report of calibration data and analysis	TBD

Table 1. Deliverables

Management Plan

Weekly general LCSR lab meetings (on Wednesday at 10 am): Here, I will report weekly progress.

Weekly meetings with Anna Goodridge (on Wednesday at 3 pm): I will find out how to best progress based on the feedback received from the general lab meeting and consult with Anna.

Meetings with Justin by schedule: If needed, I will schedule separate meetings with Justin for his consult at least once a week and in-person discussion too.

Meetings with Dr. Deepa Galaiya by schedule: If needed, I will schedule separate meetings with Dr. Galaiya for her consult, and to schedule calibration and testing.

Reading list [1]

- Gao, Anzhu, et al. "3-DOF Force-Sensing Micro-Forceps for Robot-Assisted Membrane Peeling: Intrinsic Actuation Force Modeling." *2016 6th IEEE International Conference on Biomedical Robotics and Biomechatronics (BioRob)*, 2016, doi:10.1109/biorob.2016.7523674.
- Handa, James, et al. "Design of 3-DOF Force Sensing Micro-Forceps for Robot Assisted Vitreoretinal Surgery." *IEEE Engineering in Medicine and Biology Society*, 2013, doi:10.1109/EMBC.2013.6610841
- Hong, Man Bok, and Yung-Ho Jo. "Design and Evaluation of 2-DOF Compliant Forceps With Force-Sensing Capability for Minimally Invasive Robot Surgery." *IEEE Transactions on Robotics*, vol. 28, no. 4, 2012, pp. 932–941., doi:10.1109/tro.2012.2194889.
- http://wiki.ros.org/Topics
- *ROS: an open-source Robot Operating System* Morgan Quigley* , Brian Gerkey† , Ken Conley† , Josh Faust† , Tully Foote† , Jeremy Leibs‡ , Eric Berger† , Rob Wheeler† , Andrew Ng* *Computer Science Department, Stanford University, Stanford, CA

Reference:

1. Final Project Report "Force-Sensing Forceps for Cochlear Implant Surgery" by Justin Kim, CIS-2, Spring 2021
2. https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/cochlear-implant-surgery#:~:text=A%20cochlear%20implant%20is%20a,internal%20part%20of%20the%20implant.
3. Hoskison E, Mitchell S, Coulson C. Systematic review: Radiological and histological evidence of cochlear implant insertion trauma in adult patients. Cochlear Implants Int. 2017 Jul;18(4):192-197. DOI: 10.1080/14670100.2017.1330735. Epub 2017 May 23. PMID: 28534710.
4. https://www.roswellpark.org/cancertalk/201608/advantages-robot-assisted-surgery#:~:text=Smooth%20Operations&text=With%20more%20experience%2C%20the%20surgeon,Less%20blood%20loss
5. https://www.wittenstein.de/fileadmin/Meta-Visuals/Microsites/resense/flyer/flyer-resense-hex-21.pdf [Operating Manual]