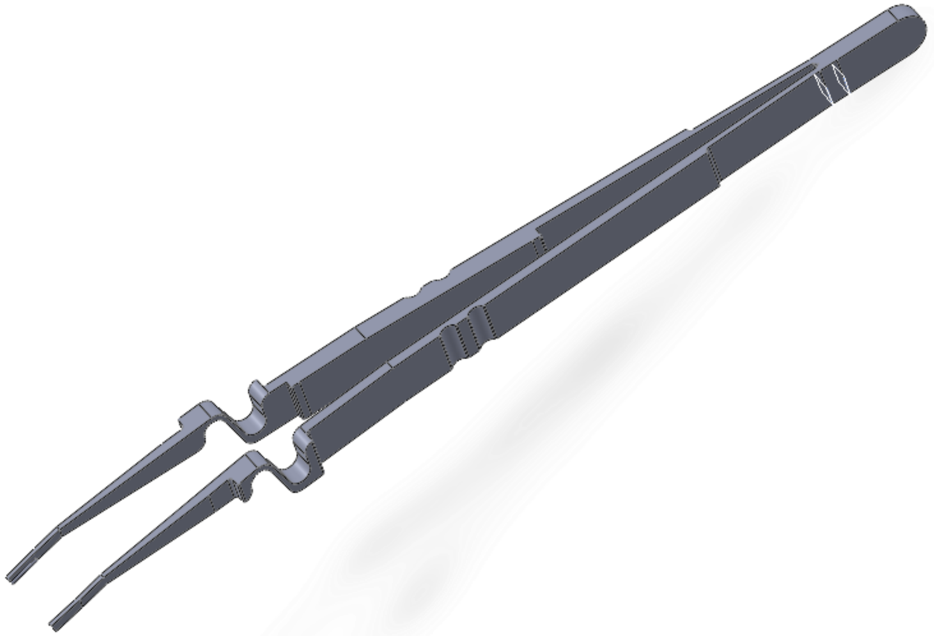
Force-Sensing Forceps for Cochlear Implant Surgery

Laboratory for Computational Sensing + Robotics



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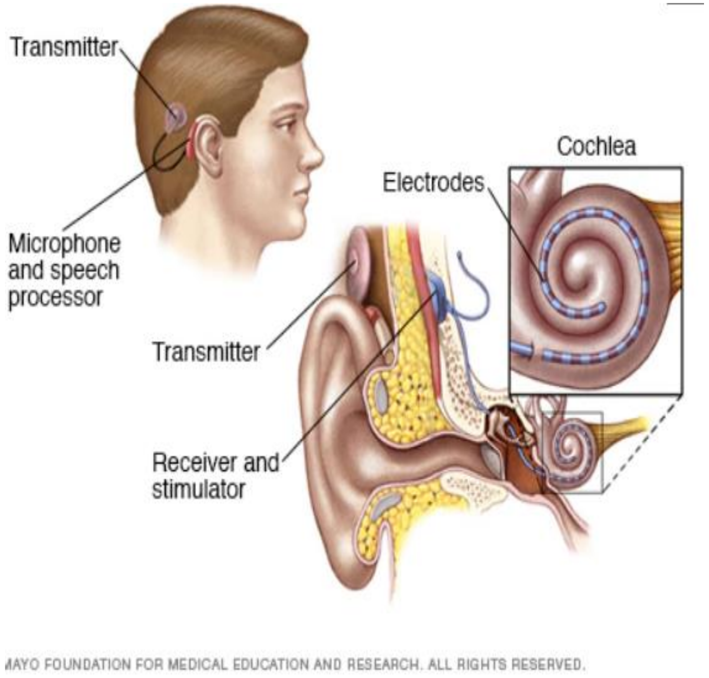
Surgeon Mentor: Dr. Deepa Galaiya

Secondary Mentor: Prof. Iulian Iordachita

Project Goal

- Problem
  - Electrode insertion during cochlear implant surgery has a high likelihood (17.6%) for trauma (Hoskison, 2017)
  - Below the resolution of surgeon tactile sensation (Seta, 2017)

- Goal
  - Design a 3 DOF force-sensing forceps to assist insertion



Paper - Relevance

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Design of 3-DOF Force Sensing Micro-Forceps for Robot Assisted Vitreoretinal Surgery

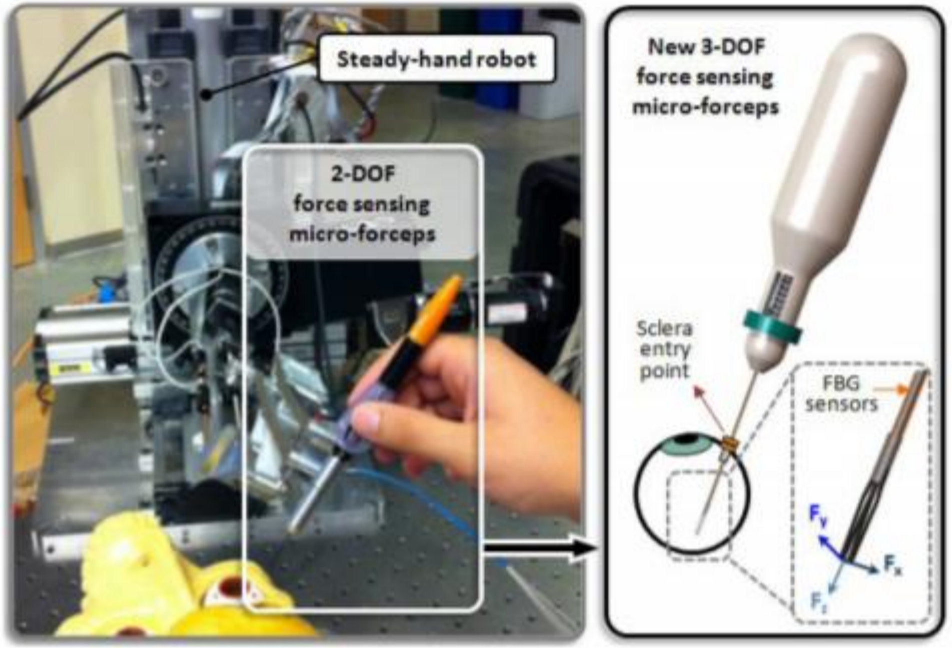
Handa, James, et al. "Design of 3-DOF Force Sensing Micro-Forceps for Robot Assisted Vitreoretinal Surgery." *IEEE Engineering in Medicine and Biology Society*, 2013, doi:10.1109/EMBC.2013.6610841.

- Significance
  - Our design is inspired by this design
  - Similar setting: measurement of forces in mN
  - 3 DOF force sensing ability
  - Good outline: design process very similar

Paper - Summary

- Summary
  - Design of 3 DOF force sensing forceps for vitreoretinal surgery

- Key Result
  - Complete design with an optimization study
  - Determined:
    - Material
    - Sensor type
    - Sensor location
  - Force sensing ability demonstrated with FEA



Handa et al (2013)

Paper - Background

Force measurement

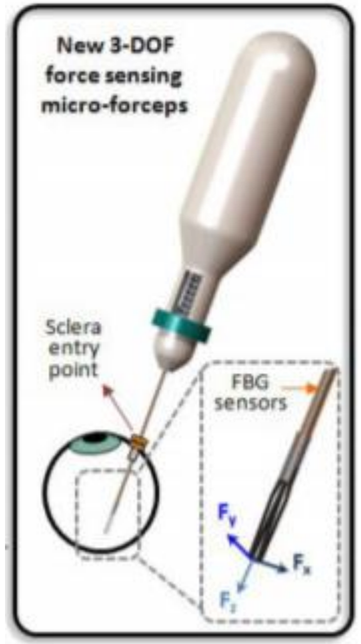
- Target: 7.5 mN

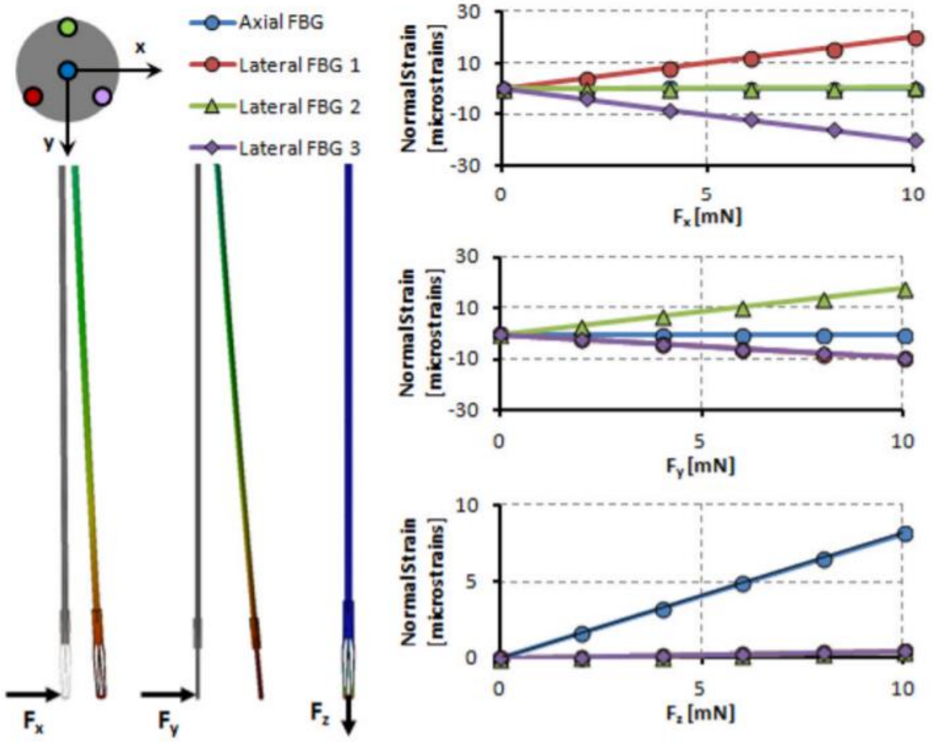
Limited Space

- Jaw length > 14mm (human eyeball 24mm dia)
- Jaw width > 0.9 mm ID (has to pass through a 20 Ga trocar)
- Biocompatibility
  - Tool is introduced into the eye

Paper – Force Sensing

- Sensor selection: FBG sensors
  - Limited space
  - Sub-mN force detection





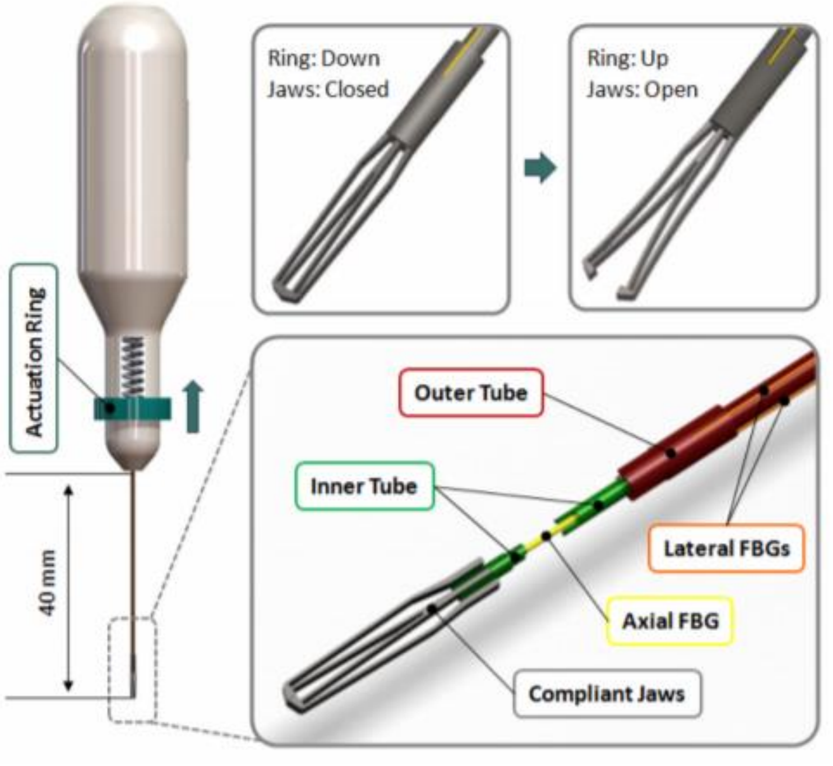
- 3DOF - 4 FBG sensors
  - 3 Lateral
  - 1 Axial
  - Strain caused by axial force on lateral FBGs are minimized by the actuation mechanism and the coupling of tubes with jaws

Handa et al (2013)

Paper - Actuation

- Spring loaded actuation
  - Actuation: relative motion of two concentric tubes
  - Sliding motion by moving the actuation ring
  - Advantage: adjustable pre-tension for controlling grasping force

- Normally closed vs. Normally open
  - Forces of interest are introduced after grasping
  - Advantageous to have 0 strain when closed



Handa et al (2013)

Paper - Optimization

- Goal: maximum sensitivity while decoupling axial-transverse force
  - Minimize actuation force
  - Maximize sensitivity
  - Maintain grasping force > 20 mN
  - Within resolution of laser cutting limits
  - Lifetime of the jaws

- Material: nitinol
  - super-elastic properties with a sheet thickness of 0.4 mm

Paper - Simulation

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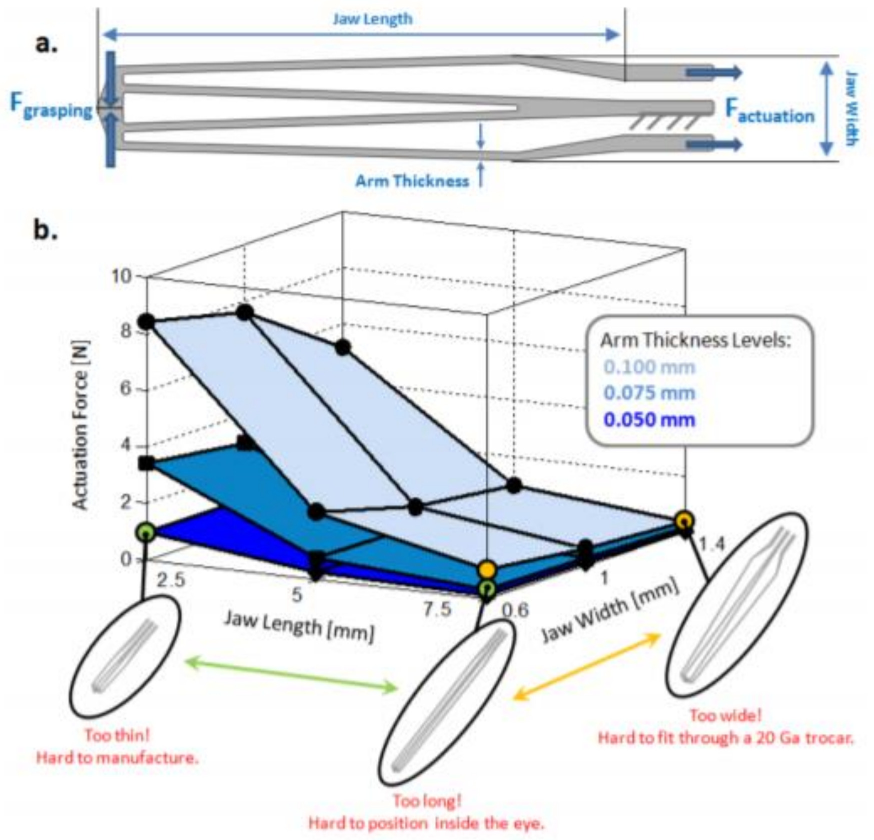
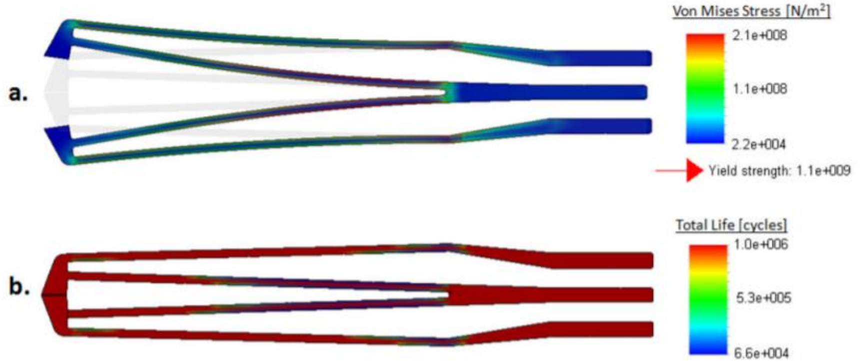
- FEA
  - Parameters
    - Arm Thickness
    - Jaw Length
    - Jaw Width
  - Calculate
    - Actuation Force

- Fatigue
  - 60,000 cycles of actuation force





Handa et al (2013)

Paper – Good and Bad

- Force sensing
  - Good
    - Good sensor choice & placement
    - 3 DOF validated from FEA
  - Missing
    - What is the resolution?
    - Is there deflection caused by actuation force (axial)
    - Combined actuation force & force from tissue manipulation

Paper – Good and Bad

- Validation
  - Good
    - Thorough FEA
  - Missing
    - Studies with physical models
    - Does force measurement match simulation?
    - What thickness did they choose for fatigue study?
    - How was the fatigue study performed?

Paper – Future work

- Produce physical prototype
  - May be new challenges in manufacturing
- Calibration & test
  - Eye model
  - Manipulate known weights
- Analysis

Paper - Relevance

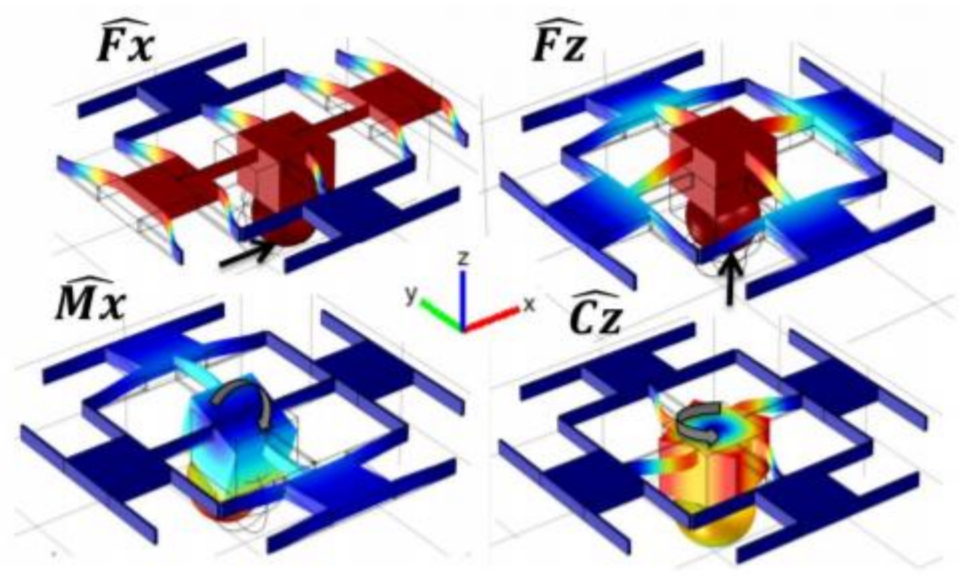
- Force
  - Paper: 7.5 mN
  - Our interest: 20 mN
- Size
  - Paper: forceps are introduced into the eye
  - Our interest: forceps do not need to enter cochlea or the inner ear cavity
- Biocompatibility
  - Both: Sterilizable and reusable

Paper - Relevance

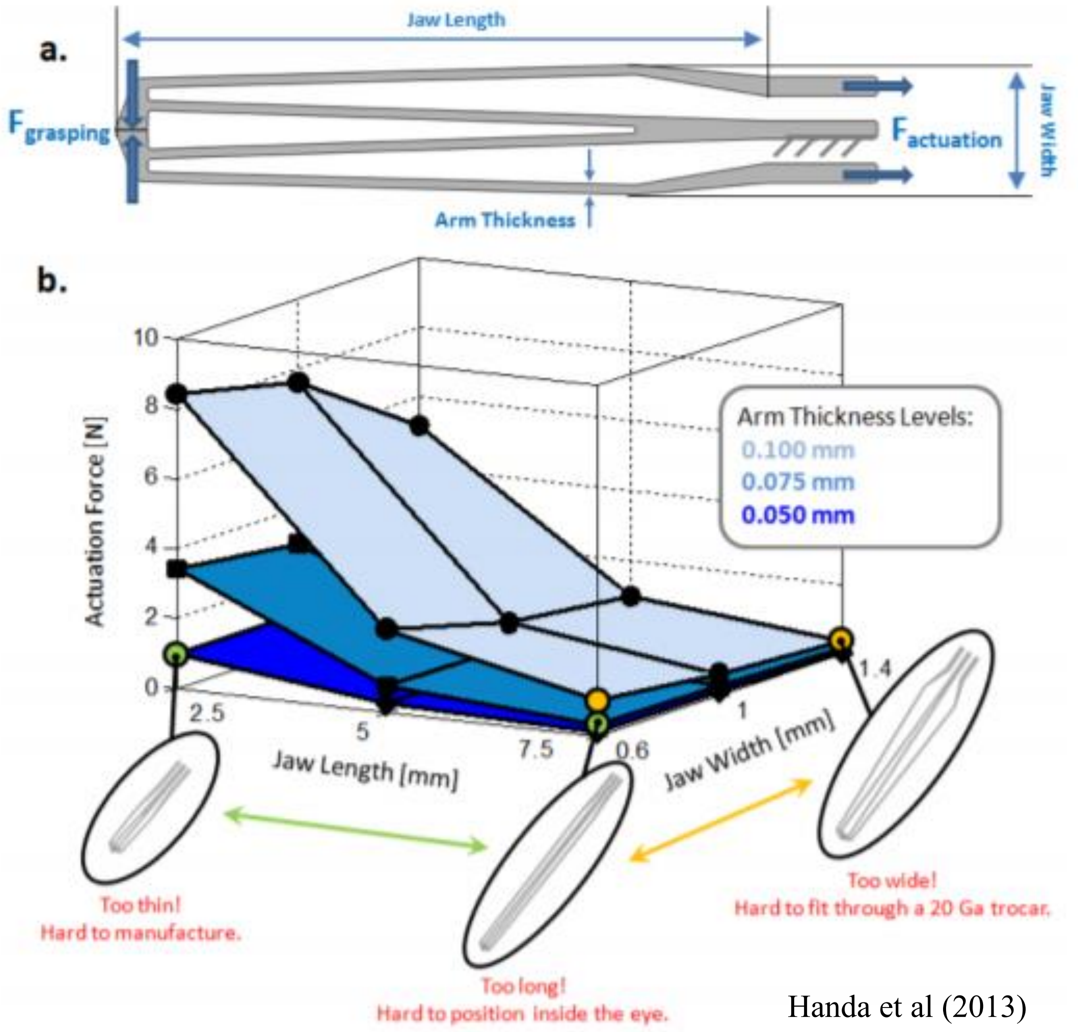
- Actuation method
  - Project
    - Pinching motion
  - Paper
    - Sliding of actuation ring
    - Spring loaded
      - Assist with controlling actuation force
    - Normally closed
      - We are also interested in forces introduced after grasping
      - May conflict with feeding motion
      - Discuss with Dr. Galaiya

Paper - Relevance

- Optimization
  - One of my milestones
  - More factors
    - Cruciform leg thickness
    - Cruciform leg length



Billot et al (2015)



Handa et al (2013)

References

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Thank you! Questions