Robotically Assisted Cochlear Imaging and Access

Team 1

- Members: Ehsan Azimi, Berk Gonenc

- Mentors: R. Taylor, I. Iordachita, J. Kang

- Clinical Mentors: J. Niparko, W. Chien
Outline

- Motivation
- Background and Specific Aims
  - Ear Anatomy and Implant Structure
  - Standard Cochlear Implant Surgery
  - Optical Coherence Tomography
  - Steady-hand Robot
- Technical Approach
- Organization and Management
  - Deliverables
  - Validation
  - Dependencies
  - Timeline
  - Management Plan
- Bibliography and Reading List
Bad news: More than 36 million Americans have some degree of hearing loss. An estimated 3/1,000 children in the US may be born with hearing loss. Hearing loss can leave you feeling isolated from friends and family.

Good news: We have Cochlear Implants!

External system
- Microphone
- Speech processor
- Transmitter

Internal system
- Receiver/stimulator
- Electrode array

Surgery required!

Source: NIH public domain image
Motivation

Lack of precise motion and feedback in the implant insertion procedure

Highly dependent on the surgeon's skills and experience

Trauma on critical tissues in Cochlear Implant Surgery

Clinical need for visualization and precise implant insertion

Hypothesis

Using robotic system and intra-operative imaging feedback can enhance the outcome of the procedure
Background & Specific Aims

MOTIVATION

BIBL & R.L.

ORG. & MNG.

TECH APPR.

B & S.A.

ERC | CISST

Ear Anatomy (courtesy Adams)

Anatomy of the inner ear (1940 knowledge builders)

Structure of the inner ear (caltech.edu)

Implant Structure Cochlea anatomy (caltech.edu)
Overview of Standard Cochlear Implant Surgery

OR setup during the Cochlear Implant procedure

Structure of a cochlear implant

Video of the surgery by Dr. Sergio Sztern (CIGNO)
What is happening inside?

- Advance Off-Stylet insertion technique is used.
- Flexible curved electrode array (1 mm diameter) is advanced into 15-20 mm long channel.
- The whole electrode is inserted until the white marker reaches cochleostomy site.
- The stylet is held stationary, electrode is deployed off the stylet to give the electrode its naturally curved shape.
- After the ribs reach the cochleostomy site, the stylet is removed.
- Timing of these steps is very critical!

Source: Thomas S. Rau et al, 2009
During insertion, the electrode should travel in Scala-Tympani with no damage to the basilar membrane.

For this, there is a critical location to begin off-stylet technique.

Electrodes should be located as close to modiolus as possible (perimodiolar position).
Background & Specific Aims

Optical Coherence Tomography (OCT)

- Up to 25 times higher resolution than anything used in clinical medicine
- Small Catheters Suitable candidate for intraoperative procedures (Fiber Optics)
- Noninvasive imaging modality
- Realtime display
- Compact and portable

Source: James Lin et al., 2008
Background & Specific Aims

**Steady-hand Robot**

- Designed for sub-mm manipulation tasks.
- Provides smooth, tremor-free, precise position control.
- Combines manipulative transparency and immediacy of hand-held tools with precision and sensitivity of a machine.
- Successful tests and improvements in retinal microsurgery.

Source: Uneri et al, 2010
Technical Approach

OCT

- 2-D OCT images

- 3-D Cochlear Model

Source: James Lin et al., 2008

Source: archive3d.net

Steady-hand Robot

- Drive OCT probe inside the cochlea.

- Eliminate hand tremor during insertion.

- Limit tool motion and prevent intra-cochlear trauma.
Technical Approach

**MOTIVATION**

**BIBL & R.L.**

**ORG. & MNG.**

**TECH APPR.**

**B & S.A.**

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**Surgical Workstation**

- Visualization & display
- Real time image and sensor processing
- 3D modeling and information fusion
- Task representation
- Safety monitoring
- Manipulation assistance and “virtual fixtures”

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**Detachable OCT probe**

**OCT Engine and Probe Control**

**Stereo video**

**Phantom or temporal bone**

**Steady Hand Robot**

**Images & videos**

**Models**

**Saved execution traces**

Source: Prof. Taylor
# MOTIVATION

## Deliverables

<table>
<thead>
<tr>
<th>Minimal</th>
<th>Expected</th>
<th>Maximal</th>
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<tbody>
<tr>
<td>1. OCT-adapter design and fabrication for the steady-hand robot</td>
<td>1. Software for controlling the motion of OCT probe inside the cochlear canal</td>
<td>1. OCT system demonstration</td>
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<tr>
<td>2. Tooling design and fabrication for electrode insertion with the steady-hand robot</td>
<td>2. 3-D reconstruction software for building cochlear canal model from OCT images</td>
<td>2. Implant insertion demonstration</td>
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<td>3. Procedure workflow for robotically assisted implantation</td>
<td>3. OCT scanning videos and images</td>
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<td>4. Implant insertion videos and images</td>
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## Validation

- Most evaluation experiments will be performed on our artificial cochlea phantom.

- The surgeons will be asked to evaluate the robotically assisted procedure based on:
  1. Intracochlear damage (number of hits and forces on Scala-Tympani walls).
  2. Operation time
  3. Final electrode position.
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<thead>
<tr>
<th>Dependency</th>
<th>Plan/Source</th>
<th>Status/Comments</th>
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<tbody>
<tr>
<td>1 OCT imaging system</td>
<td>Schedule with Dr. Kang's lab</td>
<td>Scheduled</td>
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<tr>
<td>2 CI procedure observation</td>
<td>Schedule with Dr. Niparko’s assistant</td>
<td>Done</td>
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<tr>
<td>3 Engineering and clinical mentors</td>
<td>Schedule weekly meeting with the team</td>
<td>Scheduled</td>
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<tr>
<td>4 Advance Electrode Arrays</td>
<td>Cochlear</td>
<td>We have 3; will probably need more eventually</td>
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<td>5 Biohazard and blood pathogen training</td>
<td>Register/take online class</td>
<td>Done/In progress</td>
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<tr>
<td>6 Temporal bones</td>
<td>Ask Drs. Niparko &amp; Chien</td>
<td>Received</td>
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<tr>
<td>7 Cochlear phantom with video capture capability</td>
<td>Buy/build/borrow</td>
<td>Building will require a video camera ($$)</td>
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<td>8 CISST libraries</td>
<td>Training</td>
<td>Training acquired</td>
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<tr>
<td>9 3D anatomical model of the inner ear with relevant structures</td>
<td>Order from Amazon</td>
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## Organization & Management

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### MOTIVATION

- ERC
- CISST

### BIBL & R.L.

- LABORATORY FOR COMPUTATIONAL SENSING & ROBOTICS
- THE JOHN'S HOPKINS UNIVERSITY
## Management Plan

1. Weekly meeting with mentors for establishing goals under engineering and medical experience.

2. Weekly team meeting on Wednesdays and Saturdays for sharing updates, discussion, further planning, and revising plans.

3. We are planning to spend a total of 50 hrs per week on this project.


