Robotically Assisted Cochlear Imaging and Access

Team 1

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- Clinical Mentors: J. Niparko, W. Chien

Outline

- **Introduction**
- **Specific Aims**
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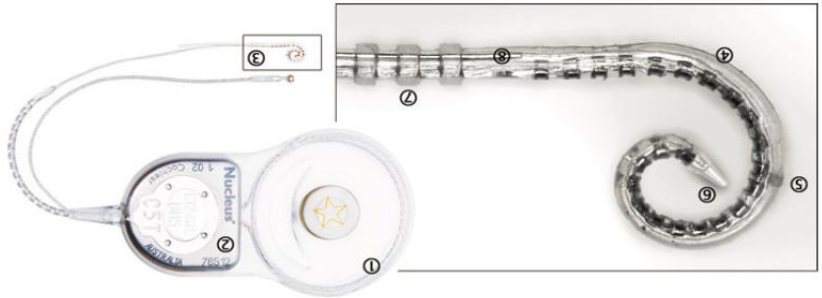
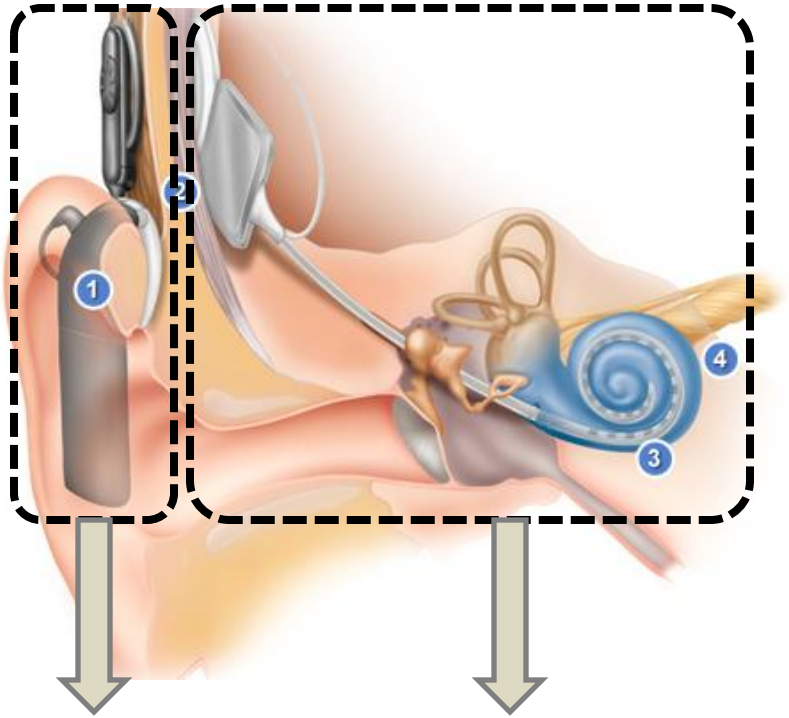
  - Project Goals
- **Progress & Revisions**
  - Ear Robot System Architecture
  - Mechanical Tools
  - OCT Imaging and Virtual Fixtures
  - Biosafety Issues
- **Project Plan & Future Work**
  - Dependencies
  - Milestones
  - Timeline
- **Bibliography and Reading List**

Introduction

Outer Ear → Middle Ear → Inner Ear



Cochlear Implants



External system

- Microphone
- Speech processor
- Transmitter

Internal system

- Receiver/stimulator
- Electrode array

Source: www.cochlear.com

Introduction

Advance Off-Stylet Technique

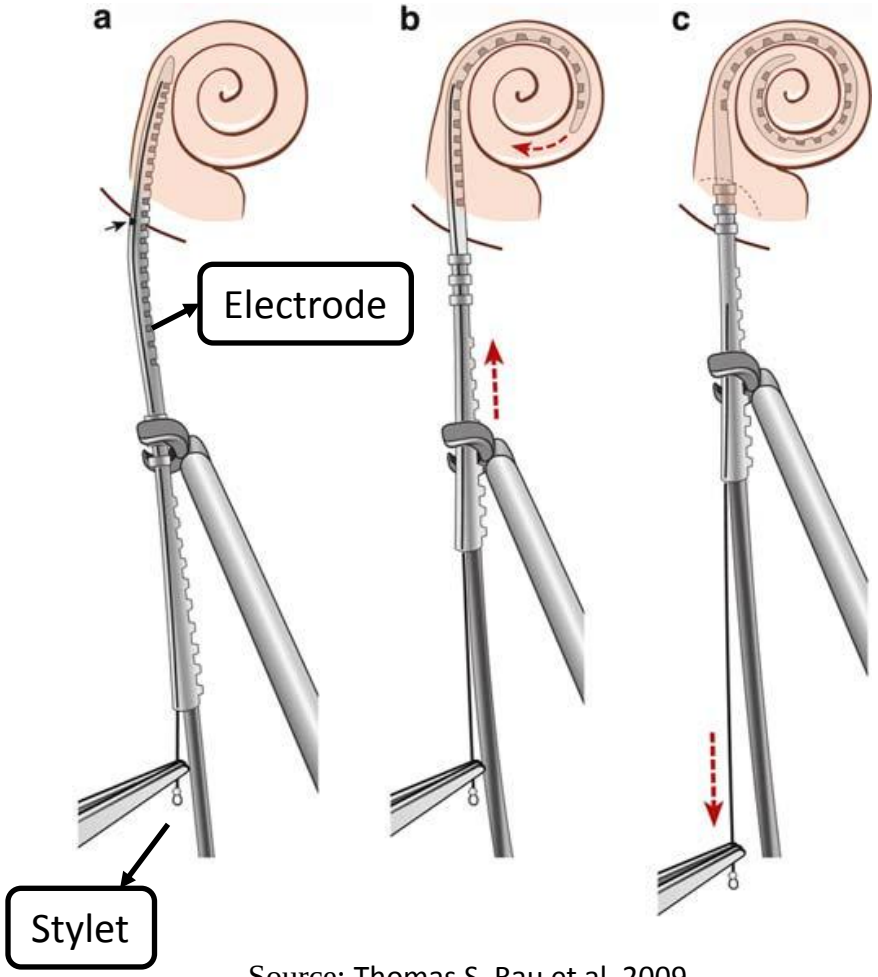
- Flexible curved electrode array (1 mm diameter) is advanced into 15-20 mm long channel in 3 steps:

  a. The whole electrode is inserted until the white marker reaches cochleostomy site.

  b. The stylet is held stationary, electrode is deployed off the stylet. The electrode takes its naturally curved shape.

  c. After the ribs reach the cochleostomy site, the stylet is removed.

- Location of these steps is very critical!



Source: Thomas S. Rau et al, 2009

➢ Specific Aims

- Clinical Goals
- Project Goals

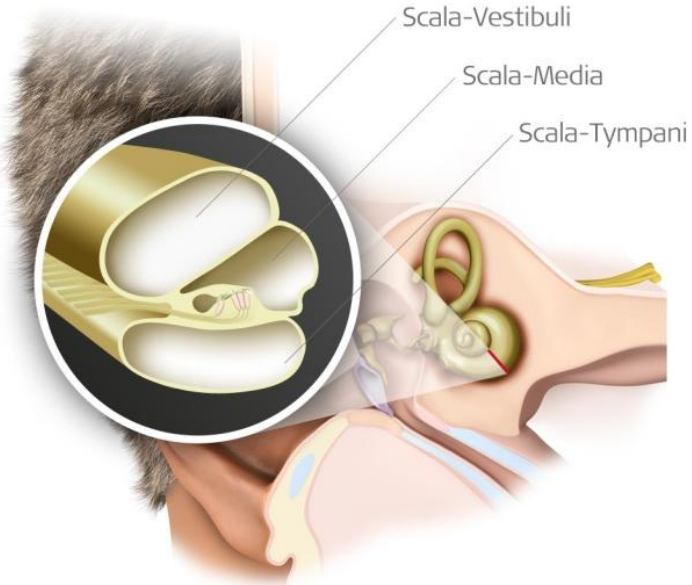
Specific Aims

Clinical Goals

1. The electrode should travel in Scala-Tympani with **NO DAMAGE** to the basilar membrane.

2. The electrode should be located as **CLOSE TO MODIOLUS** as possible.

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



Source: www.medel.com

Source: www.utsouthwestern.edu

Specific Aims

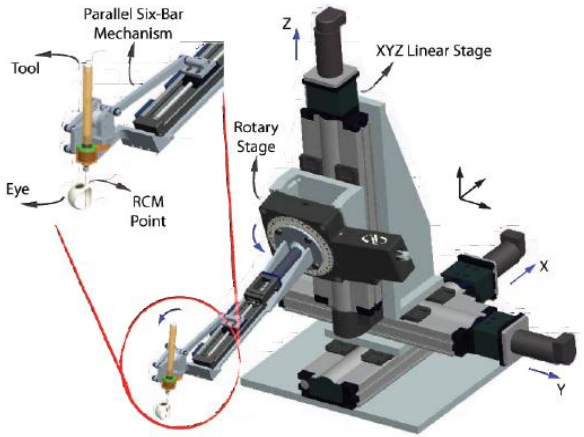
Project Goals

1. Use Optical Coherence Tomography (OCT) to build 3-D cochlea model.

2. Use Steady-hand Robot to eliminate hand-tremor.

3. Implement virtual fixtures for use with the robot for optimal electrode placement.

Steady-hand Robot



Source: Uneri et al, 2010

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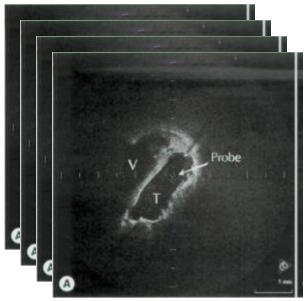
OCT Imaging



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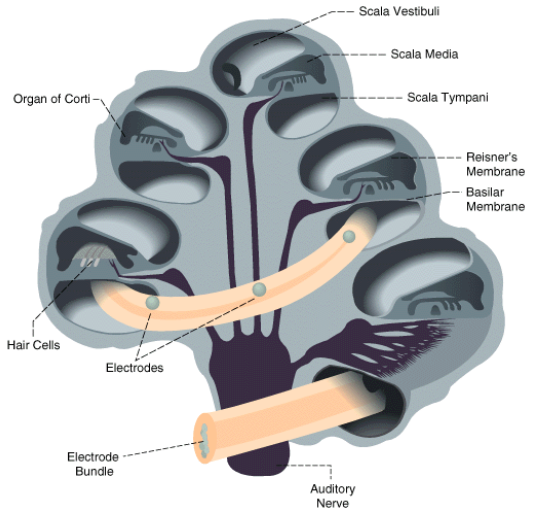


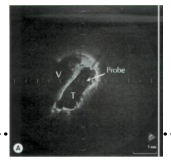
Source: www. hms.harvard.edu

➢ Progress & Revisions

- Ear Robot System Architecture
- Mechanical Tools
- OCT Imaging and Virtual Fixtures
- Biosafety Issues

Progress & Revisions

Ear Robot System Architecture



Imaging/ OCT

Model Segmentation

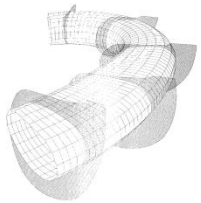
Model (OCT)

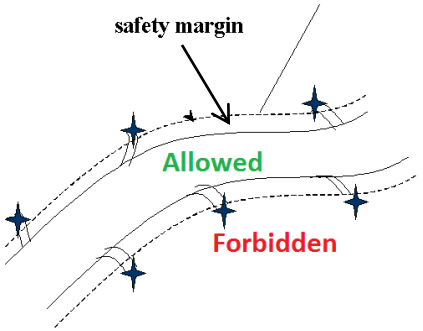
Generate 3D Cochlea Model

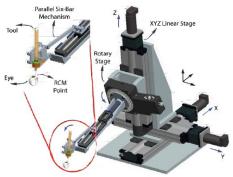
Interactive Display

Obtainingg Frame Features

Preoperative imaging







Registration on the Ear Robot Frame

Virtual Fixtures

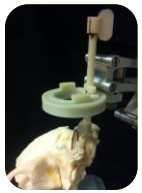
Constrain motion

Electrode Insertion

End effector position

Electrode Localization

Resistive Force



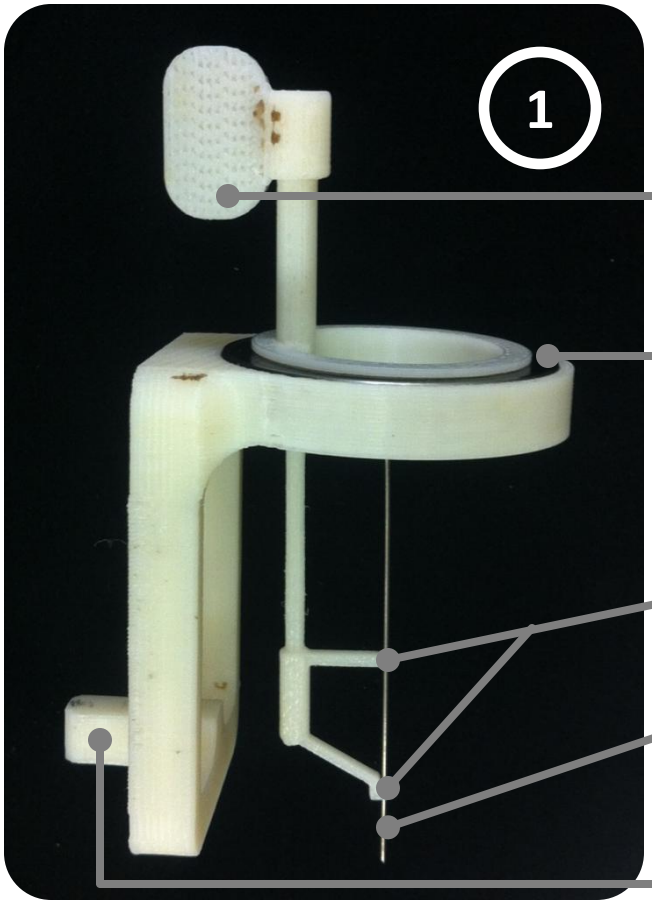
Mechanical Tools

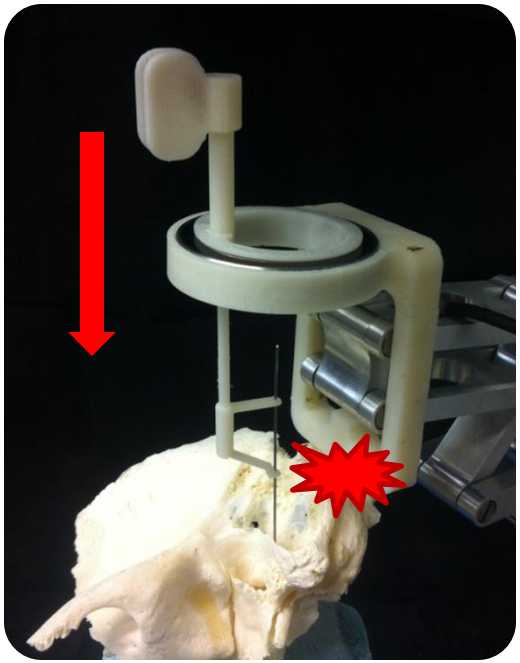
Safety margin

Virtual contact

Progress & Revisions

Mechanical Tools

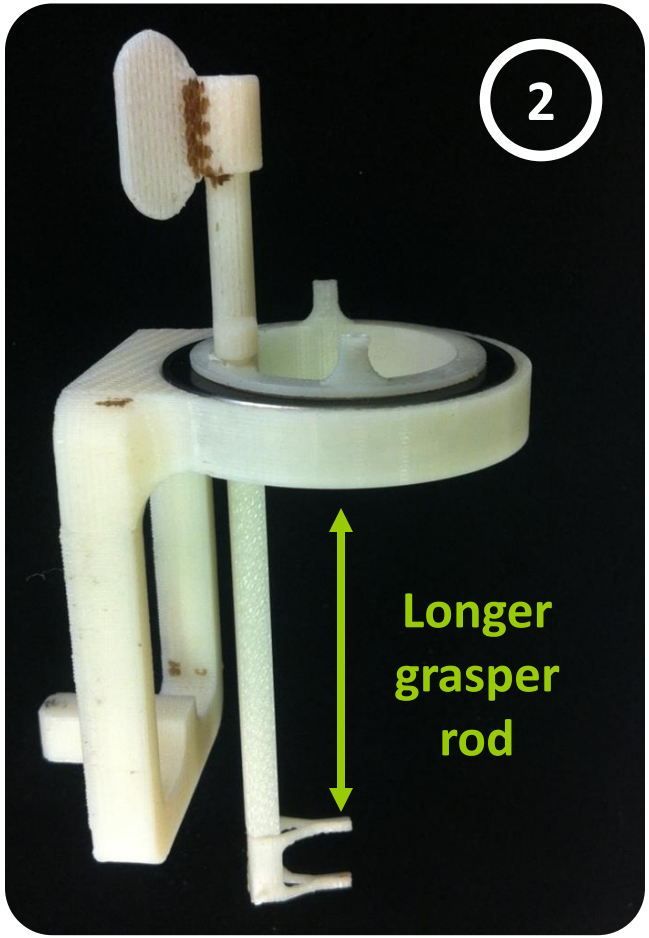


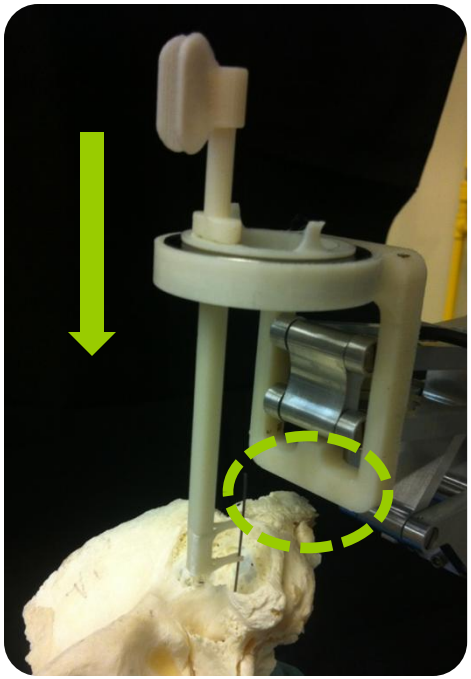


X Collision with the temporal bone while lowering

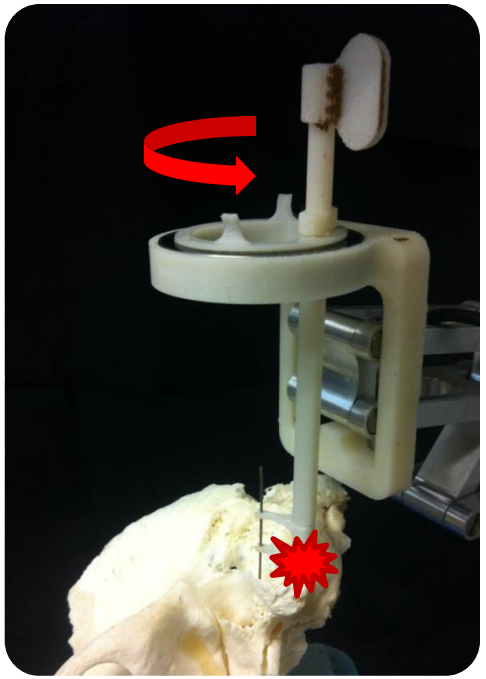
Progress & Revisions

Mechanical Tools





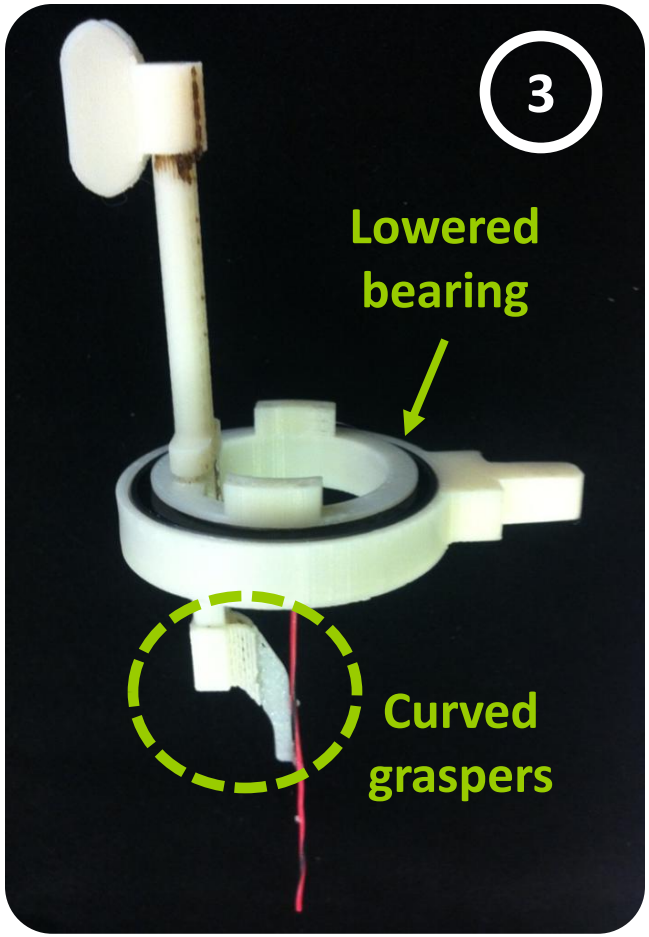
✓ No collision while lowering

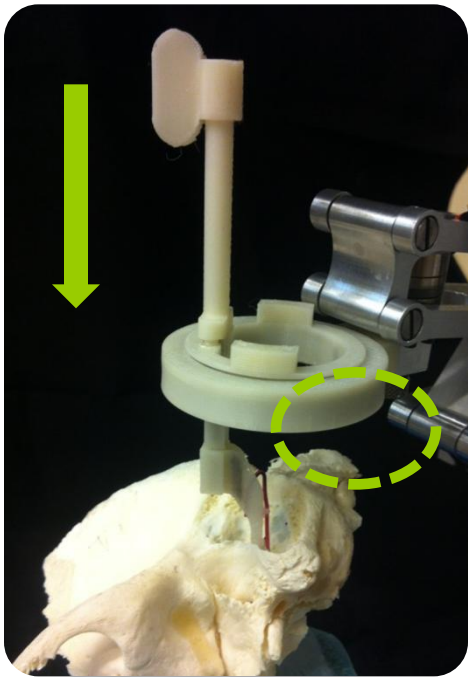


X Collision during axial rotation

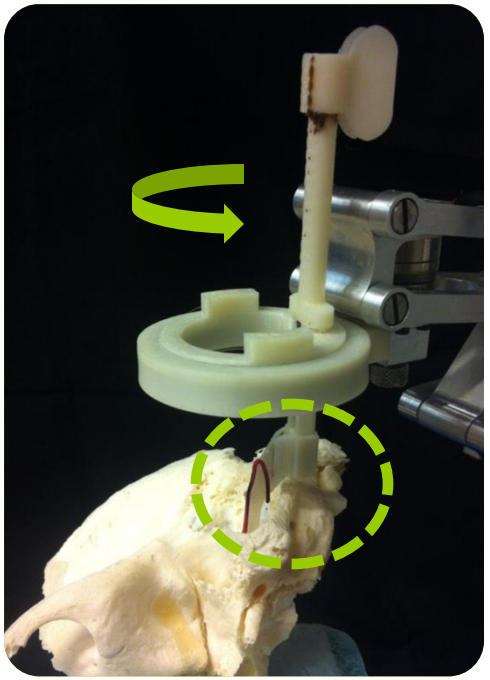
Progress & Revisions

Mechanical Tools





✓ No collision while lowering



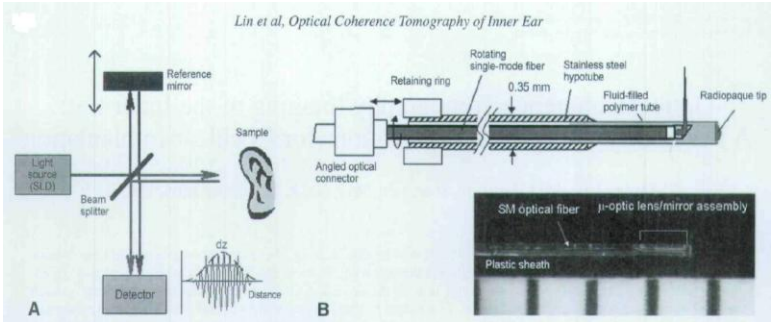
✓ No collision during rotation

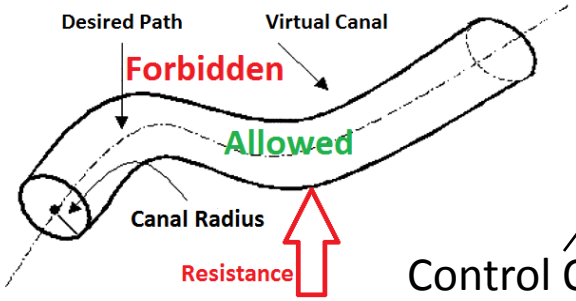
Progress & Revisions

OCT Imaging and Virtual Fixtures

- **Different Approaches for OCT**

1. Rotating Side view probe
2. Front view OCT probe
3. Fiber bundles
4. Microscopic view as the sample arm



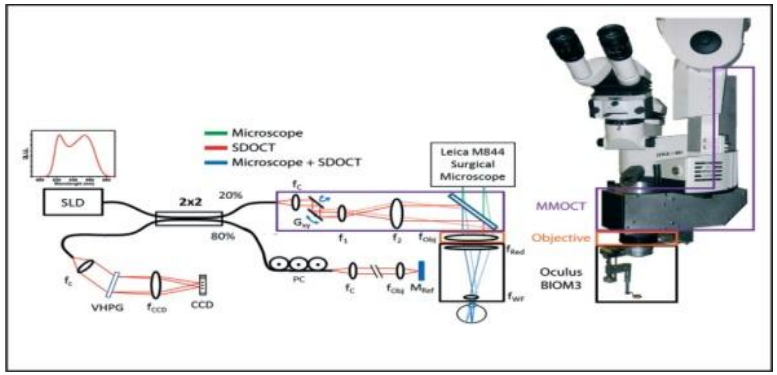


$$V = \frac{1}{K} F$$

User Input

Control Output

Damping



Source: James Lin et al., 2008

- **Virtual Fixture Implementation**
  - Using Fixtures as a control law in steady hand paradigm
  - Constraining virtual contact between electrode tip and cochlear channel
  - Modeling the relationship between velocity and force by a linear viscous friction law
  - Defining a direction of motion for the electrode tip along a Cartesian curve in space

Progress & Revisions

Biosafety Issues

Registration for fixed cadaveric temporal bone

- Specimens preparation (minimize surface area exposure)
- Potential hazards (human pathogens and chemical exposure)
- Experimental Protocol(access through small hole)
- Safety requirements
  - Biohazard and BloodBorne Pathogen Training
  - Safety Gear (disposable Nitrile gloves and facial shields)
- Cadaver Parts Disposal (at JHMI under the guidance)
- Transportation (Triple packaging for leaks or spills)

➢ Project Plan & Future Work

- Dependencies
- Deliverables
- Timeline

Project Plan & Future Work

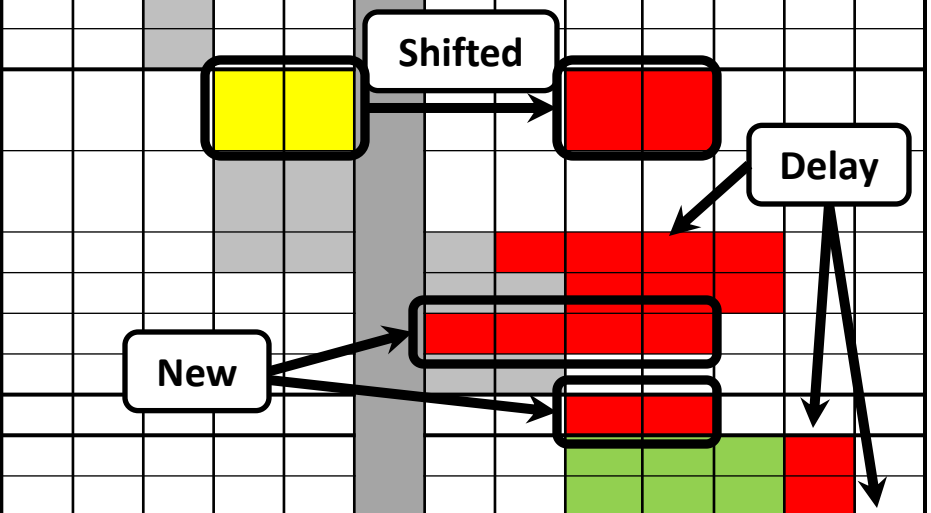
	Dependency	Plan/Source	Status/Comments	
1	OCT imaging system	Schedule with Dr. Kang's lab	Need rescheduling	Delay
2	CI procedure observation	Schedule with Dr. Niparko's assistant	Done	
3	Engineering and clinical mentors	Schedule weekly meeting with the team	Scheduled	
4	Advance Electrode Arrays	Cochlear	We received 5	Updated
5	Bloodborne Pathogen training	Register/ take online class	Done	
6	Fire Safety and Hazard Communication	Register/ take online class	Done	New
7	Temporal bones	Ask Drs. Niparko & Chien	Received	
8	Cochlear phantom with video capture capability	Buy/build/borrow	Building will require a video camera ($$)	
9	CISST libraries	Training	Training acquired	
10	3D anatomical model of the inner ear with relevant structures	Order from Amazon	Received	

Project Plan & Future Work

Deliverables	
Minimal	**1.** OCT-adapter design and fabrication for the steady-hand robot
	2. Tooling design and fabrication for electrode insertion with the steady-hand robot
	3. Procedure workflow for robotically assisted implantation
Expected	**1.** Software for controlling the motion of OCT probe inside the cochlear canal
	2. 3-D reconstruction software for building cochlear canal model from OCT images
	3. OCT scanning videos and images
	4. Implant insertion videos and images
Maximal	**1.** OCT system demonstration
	2. Implant insertion demonstration

Project Plan & Future Work

Period	Task	2/13	2/20	2/27	3/05	3/12	3/19	3/26	4/02	4/09	4/16	4/23	4/30	5/07
Planning Period	Literature Survey													
	OR visit													
	Detailed Problem Definition and Design Concepts													
	Evaluation of Concepts													
	Project Proposal Presentation													
Design and Fabrication Period	Design of OCT Adapter (CAD Model) and Ordering Materials													
	Design of Implant Manipulating Adapter (CAD Model) and Ordering Materials													
	Development of OCT Control Software													
	Development of 3-D Reconstruction Software													
	Implementing Virtual Fixtures													
	Fabrication of Prototypes													
	Manufacturing the Functional Insertion Tool													
OCT Testing Period	OCT Tests on Temporal Bone Model													
	Modifications and Debugging													
	OCT System Demonstration													
Robot Testing Period	Electrode Insertion Tests on Temporal Bone Model													
	Modifications and Debugging													
	Electrode Insertion Demonstration													
Final Presentation														



Bibliography & Reading List

[1] Lenarz T, Stöver T, Buechner A et al (2006) Temporal bone results and hearing preservation with a new straight electrode.

[2] Roland P, GstöttnerW,AdunkaO (2005) Method for hearing preservation in cochlear implant surgery.

[3] AdunkaOF, Pillsbury HC,Kiefer J (2006) Combining perimodiolar electrode placement and atraumatic insertion properties in cochlear implantation—fact or fantasy?

[4] Adunka OF, Radeloff A, Gstoettner WK et al (2007) Scala tympani cochleostomy. II. Topography and histology.

[5] Briggs RJS, Tykocinski M, Stidham K et al (2005) Cochleostomy site: implications for electrode placement and hearingbpreservation.

[6] Eshraghi AA, Yang NW, Balkany TJ (2003) Comparative study of cochlear damage with three perimodiolar electrode designs.

[7] Roland PS,WrightCG (2006) Surgical aspects of cochlear implantation: mechanisms of insertional trauma.

[8] Stöver T, Issing P, Graurock G et al (2005) Evaluation of the advance off-stylet insertion technique and the cochlear insertion tool in temporal bones.

[9] Wardrop P, Whinney D, Rebscher SJ et al (2003) A temporal bone study of insertion trauma and intracochlear position of cochlear implant electrodes. I. Comparison of Nucleus banded and Nucleus Contour electrodes.

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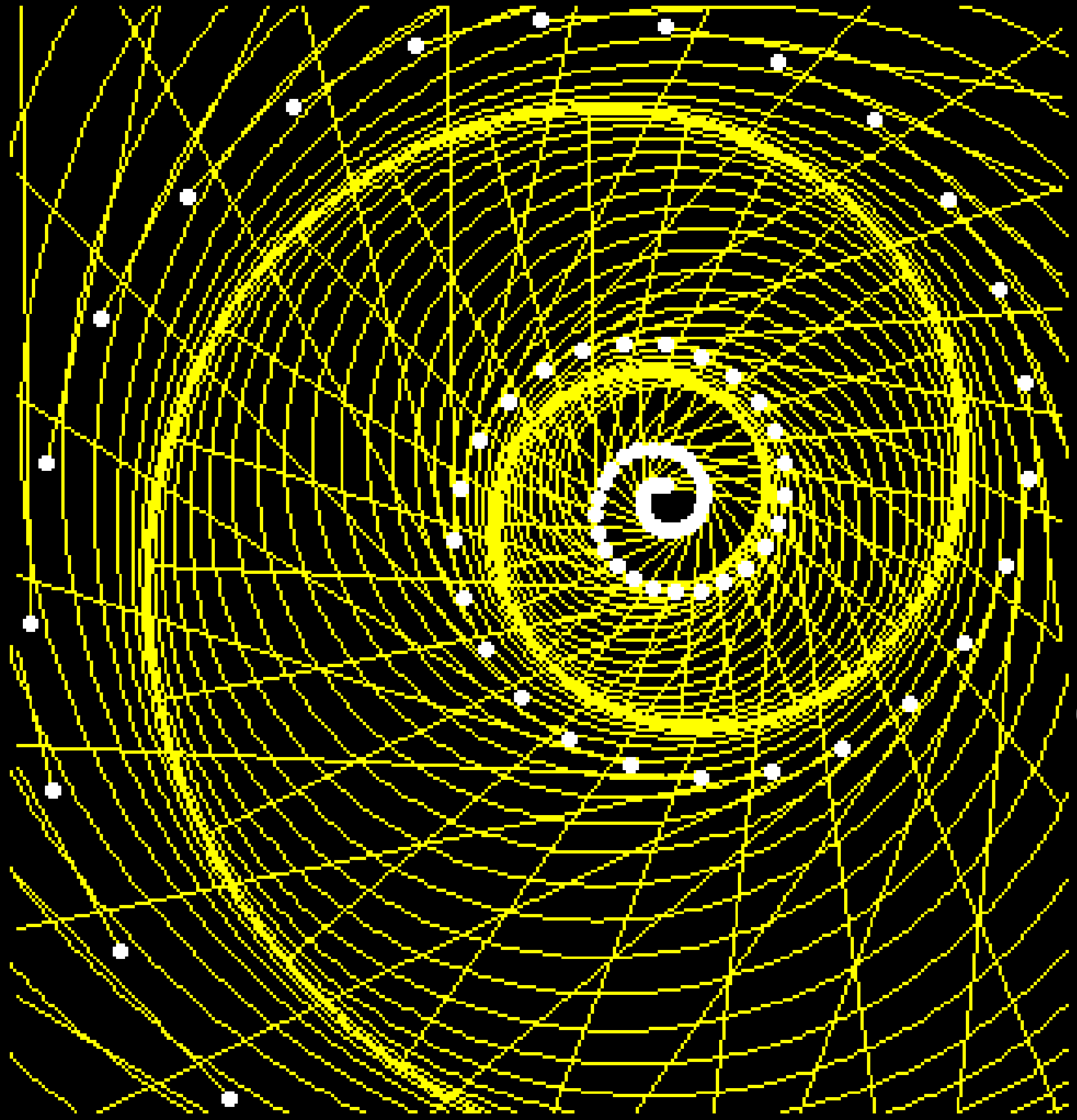
[11] Hussong A, Rau T, Ortmaier T et al (2010) An automated insertion tool for cochlear implants: another step towards atraumatic cochlear implant surgery.



Questions & Comments