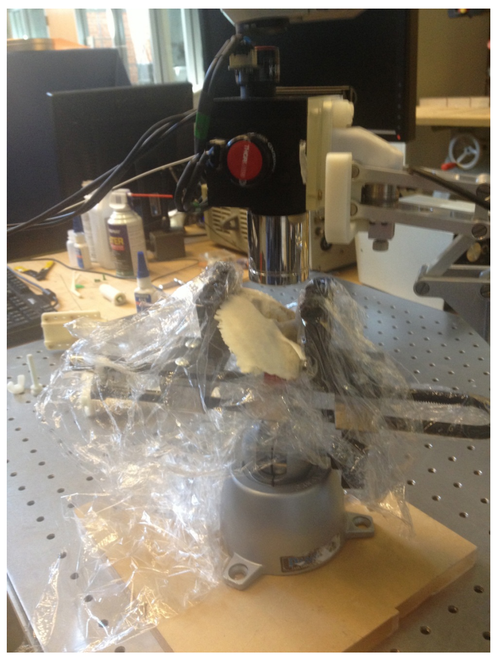
Constructing a Model of the Cochlea from OCT Images

Computer Integrated Surgery II
Spring, 2013
Paul Wilkening and Emily Daggett, under the auspices of Prof. Russell Taylor and Prof. Jin Kang

Introduction

- Cochlear implants are used to restore hearing in deaf and hard-of-hearing patients by augmenting cochlear functionality.
- We propose a system for robot-assisted insertion of cochlear implants.
- We created models of the cochlea based on Bulk Scan Volumes and Side-View Probe B-scans.
- We combined these separate models to create a single, more accurate cochlear model.
- Combined model was used to enact virtual fixtures which constrain motion of the robot to the axis of the cochlea for cochlear implant insertion.
- This will improve upon standard practice in cochlear implant insertion surgery.

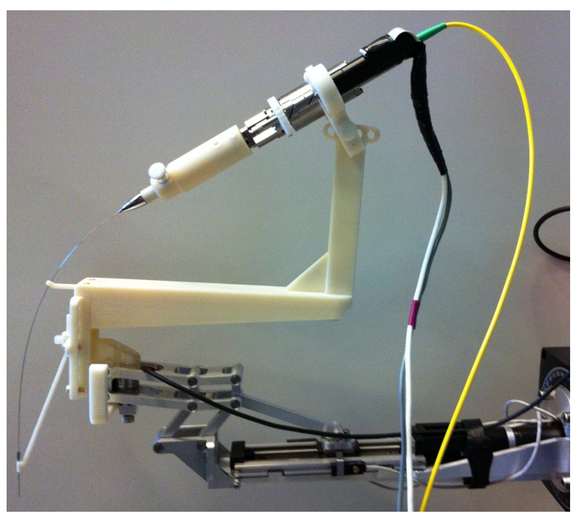


Bulk Scan Setup

Cochlear Implant in Phantom Cochlea
Positioned at Optimal Depth of Insertion

Problems in Current Insertion Practice

- **Lack of Visibility**
  - Surgeon must insert implant into cochlea without any visualization.
  - Only visual feedback is mark on implant indicating maximum depth of insertion.
- **Sensitivity of Cochlea**
  - Small forces, on the order of surgeon's hand tremor, can damage hairs inside cochlea and basilar membrane, impairing residual hearing.
- **Required Precision**
  - Incorrect insertion may necessitate subsequent insertion surgery.

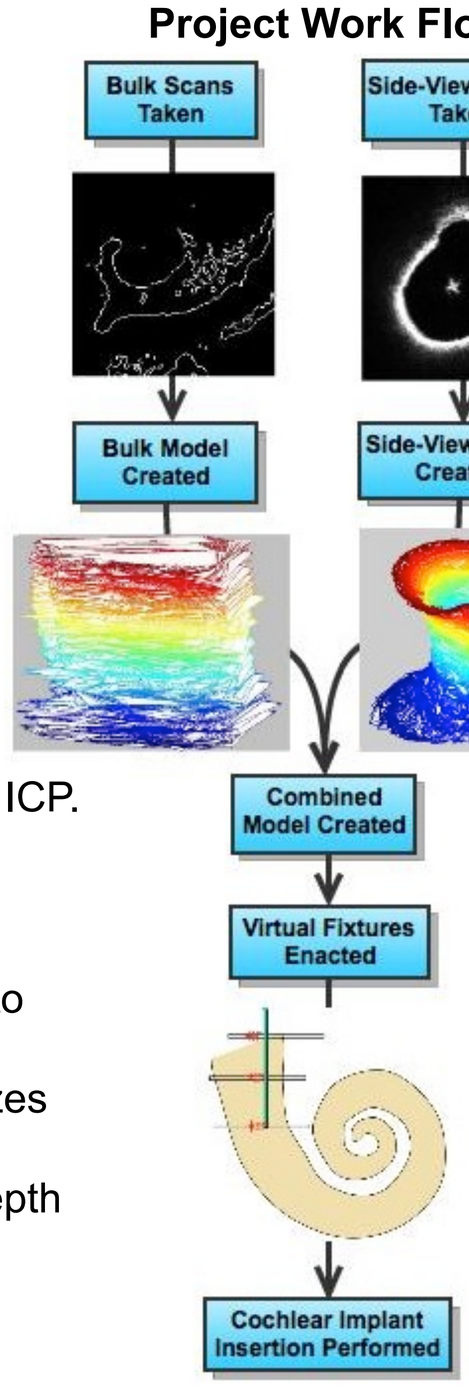


Side-View Probe Setup

Methods

- **Bulk Scan OCT Imaging**
  - 5mm x 5 mm x 5 mm volumes of cochlea captured and stitched together.
  - Contours created from volume slices and used to create mesh model.
- **Side-View OCT Imaging**
  - Probe rotated inside cochlea and B-scans taken at several depths.
  - Contours created from B-scans and used to create mesh model.
- **Combined Model**
  - Transformation between models found using ICP.
  - Models combined by averaging contours.
- **Virtual Fixtures**
  - Using contour data, find vectors from tool tip position to cochlear axis at several depths into the cochlea.
  - Find incremental motion of robot that minimizes these vectors.
  - Stop motion when tool tip reaches optimal depth of insertion.

Project Work Flow



Outcomes

- Performed calibration between robot and bulk scanner, side-view probe.
- Individual and combined models created.
- Hand-tremor reduced with assistance of Steady-Hand Robot.
- Virtual fixtures enacted.

Future Work

- Improve process for creating side-view probe for stronger signal in wet bone and higher durability.
- Improve combined comprehensive model.
- Streamline system for clinical use.
- Paul will continue on this project in Fall 2013.

Lessons Learned

- Familiarity with OCT imaging and virtual fixture constrained optimization algorithms.
- Communication among members of the research team and owners of project dependencies is vital for success.
- It is important to be flexible with any project timeline as difficulties are bound to arise.

Credits

- Paul Wilkening – Side-View/Combined Models and Virtual Fixtures
- Emily Daggett – Bulk/Combined Models

Acknowledgements

- Saumya Gurbani for side-view probe imaging software and B-scan image.
- Mingtao Zhao for bulk scan imaging software.
- Prof. Jin Kang for OCT system.
- Prof. Russell Taylor for support and advisement, and for virtual fixture image.
- Berk Gonenc for equipment setup images.
- Support by Cochlear Ltd. and Core NSF CISST/ERC.

Publications

- Kapoor, A., Li, M., & Taylor, R. (2006). Constrained control for surgical assitant robots. *Proceedings of the 2006 IEEE International Conference on Robotics and Automation,* Orlando, Florida.
- Lin, J., Staecker, H., & Jafri, M. S. (2008). Optical coherence tomography imaging of the inner ear: A feasibility study with implications for cochlear implantation. *Annals of Otology, Rhinology & Laryngology, 117*(5), 341-346.
- Zhang, J., Wei, W., Ding, J., Roland, J. T. J., Manolidis, S., & Simaan, N. (2010). Inroads toward robot-assisted cochlear implant surgery using steerable electrode arrays. *Otology & Neurotology.*