Guidance for Skullbase Surgery

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Team members: Allen Zhu, Grace Yeo
Mentors: Peter Kazanzides, Muyinatu Bell

Motivation/Relevance

- In 2008, Dr. Kazanzides et al. developed an integrated system for planning, navigation and robotic assistance for skull base surgery
- **Co-operative control**
- **Virtual fixtures**: Enforce safety constraints
- **High ergonomic benefits**: Less stress and fatigue on surgeon

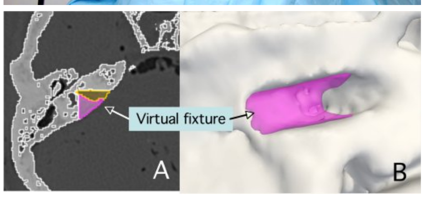

Image source: Xia, T., Baird, C., Jallo, G., Hayes, K., Nakajima, N., Hata, N. and Kazanzides, P. (2008), An integrated system for planning, navigation and robotic assistance for skull base surgery. Int. J. Med. Robotics Comput. Assist. Surg., 4: 321–330. doi: 10.1002/rcs.213

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Motivation/Relevance

- **Skull base surgery** is extremely challenging due to the number of critical structures present
- The **transphenoidal approach** is preferred in adults for the **removal of pituitary tumors**

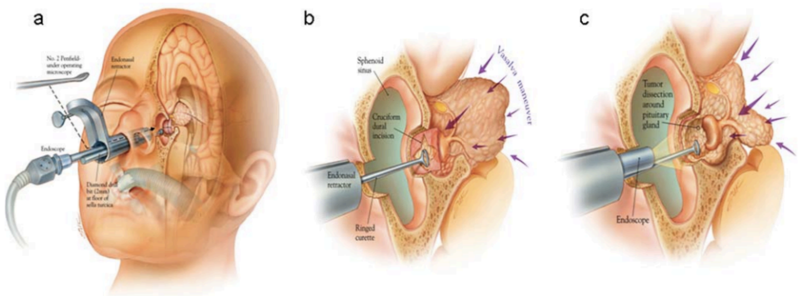

Image source: JF Frazier, K Chaichana, GI Jallo, A Quiñones-Hinojosa, "Combined endoscopic and microscopic management of pediatric pituitary region tumors through one nostril: technical note with case illustrations", *Childs Nervous System*, Vol 24, pp 1469–1478, 2008

Motivation/Relevance

- **Technically difficult** in children
  - Smaller anatomy (~1cm window)
  - Unaerated Sinuses
- Critical structures to avoid:
  - **Carotid artery (either side of the sphenoid window)**
  - Optic nerve
- Uncertainty in registration
  - Accepted **clinical errors** are **+- 1mm**. However, the typical overcut was 1-2mm, with max overcut of 3mm

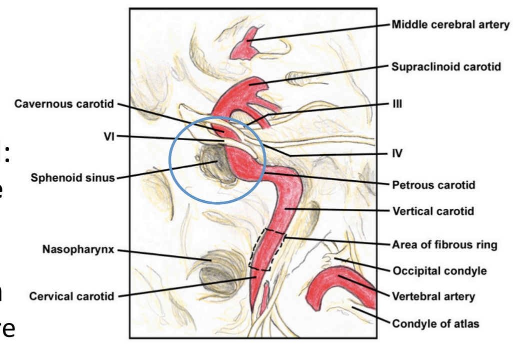

Image source: http://emedicine.medscape.com/article/882627-overview

Our Goal:

Improve accuracy using **intra-operative sensing/imaging** so as to **protect critical structures** during drilling

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Approach

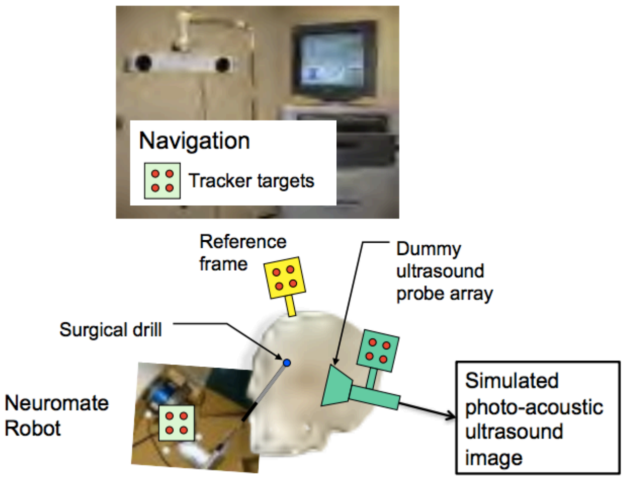

Image source: Dr. Kazanzides

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Approach

- Photo-acoustic imaging can be accomplished using a **pulsed laser** and an **ultrasound probe**
- Structures respond differently to **different wavelengths**

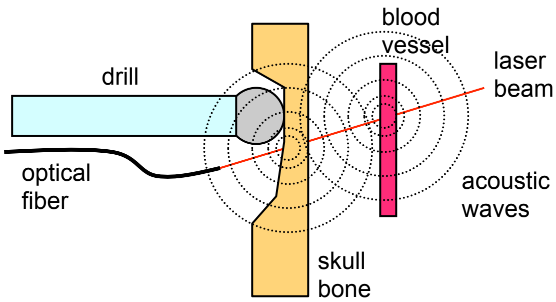

Image source: Dr. Kazanzides

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Approach

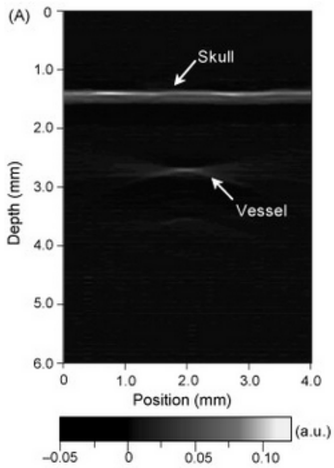
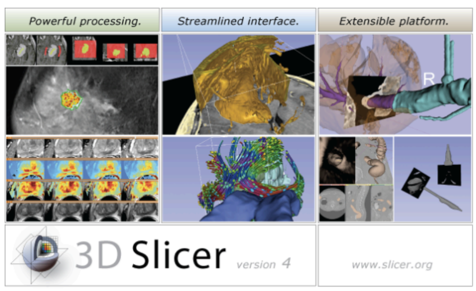


Image source: Xueding Wang, David L. Chamberland, Guohua Xi, Noninvasive reflection mode photoacoustic imaging through infant skull toward imaging of neonatal brains, Journal of Neuroscience Methods, Volume 168, Issue 2, 15 March 2008, Pages 412-421, ISSN 0165-0270, 10.1016/j.jneumeth.2007.11.007



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Approach

Sensing and control to reduce model registration uncertainty

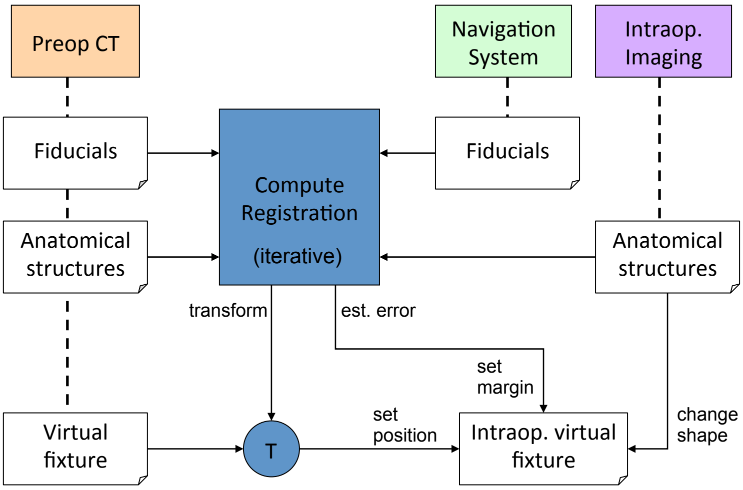

Image source: Dr. Kazanzides

Deliverables (Minimum)

- Simple simulation of photo-acoustic imaging based on tracked location of hand-held tool and probe with respect to anatomy (Without Neuromate® robot)
- Registration using intraoperative imaging
- Experiments with simple foam block and rubber tubing

Deliverables (Expected)

- More realistic simulation of photo-acoustic imaging based on tracked location of hand-held tool with respect to anatomy using the Matlab package kwave
- Or: Simple simulation of photo-acoustic imaging based on tracked location of tool (with Neuromate® robot) and probe with respect to anatomy

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Deliverables (Maximum)

- More realistic simulation of photo-acoustic imaging based on tracked location of tool (with Neuromate® robot) and probe with respect to anatomy using the Matlab package k-wave
- Experiments with a more realistic skull phantom

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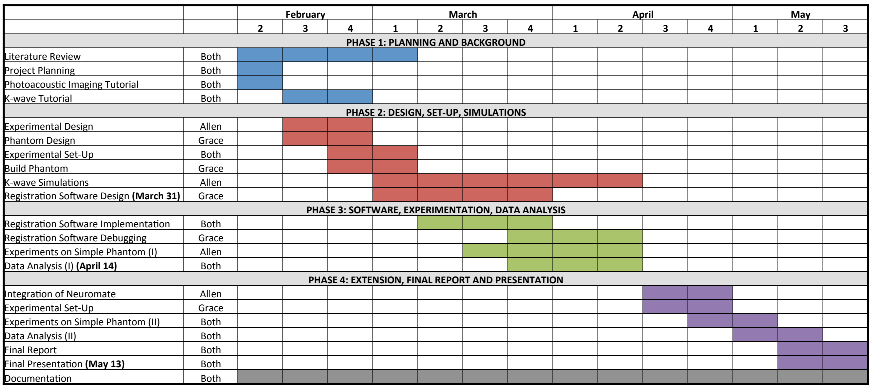
Key Dates & Assigned Responsibilities



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Dependencies

Dependency	Date	Resolution/Plan	Consequences
1) Access to labs in Hackerman	02/23	Waiting for approval	Cannot perform experiments (all)
2) Access to robotorium svn repository	02/23	Already obtained access Dr. Kazanzides will be introducing us to the repository early next week.	Resolved
3) Tutorials for ultrasound/K-wave	03/01	First tutorial on Go through examples on K-wave website	Cannot create simulation (expected)
4) Learn to use navigation system, CISST Library, 3D slicer	03/01	Go through tutorials	Cannot perform experiments (all)

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Dependencies

Dependency	Date	Resolution/Plan	Consequences
5) Access to CT scan	NA	Dr. Kazanzides has access to a 20cm by 20cm CT scan	Resolved
6) Access to a computational platform	03/01	Assess computational requirements for K-wave package and speak to Dr. Bell	Cannot perform experiments (expected)
7) Access to NeuroMate ® Robot	04/01	Dr. Kazanzides will be moving it to the Homewood campus in the coming week	Cannot perform experiments (expected, max)
8) Phantom Skull	TBD	Dr. Kazanzides will check and buy us a new skull if necessary (He has one that is quite old)	Cannot perform experiments with phantom skull (max)

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Management Plan

- Tutorials on Ultrasound Imaging and use of the K-wave Matlab toolbox with Dr. Bell
- Bimonthly meetings with Dr. Kazanzides and Dr. Bell
- Constant communication with Dr. Kazanzides and Dr. Bell via email
- Bimonthly updates on wiki page on progress of projects
- Updates of all progress/problems to Dr. Taylor
- In-Class Presentations for feedback from Dr. Taylor and class

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Reading List

(Endonasal) Skullbase Surgery

- Xia, T., Baird, C., Jallo, G., Hayes, K., Nakajima, N., Hata, N. and Kazanzides, P. (2008), An integrated system for planning, navigation and robotic assistance for skull base surgery. Int. J. Med. Robotics Comput. Assist. Surg., 4: 321–330. doi: 10.1002/rcs.213
- JF Frazier, K Chaichana, GI Jallo, A Quiñones-Hinojosa, "Combined endoscopic and microscopic management of pediatric pituitary region tumors through one nostril: technical note with case illustrations", *Childs Nervous System*, Vol 24, pp 1469–1478, 2008
- Cappabianca P, Cavallo LM, Colao A, et al. Surgical complications associated with the endoscopic endonasal transsphenoidal approach for pituitary adenomas. J Neurosurg 2002;97:293–8.

Photoacoustic Imaging/Modeling Photoacoustic Imaging

- Xueding Wang, David L. Chamberland, Guohua Xi, Noninvasive reflection mode photoacoustic imaging through infant skull toward imaging of neonatal brains, Journal of Neuroscience Methods, Volume 168, Issue 2, 15 March 2008, Pages 412-421, ISSN 0165-0270, 10.1016/j.jneumeth.2007.11.007
- B. E. Treeby and B. T. Cox, "k-Wave: MATLAB toolbox for the simulation and reconstruction of photoacoustic wave-fields," J. Biomed. Opt., vol. 15, no. 2, p. 021314, 2010
- Kolkman, R., Steenbergen, W., and van Leeuwen, T., "In vivo photoacoustic imaging of blood vessels with a pulsed laser diode," Lasers in medical science 21(3), 134–139 (2006).

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