Guidance for Skullbase Surgery

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

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**

![Images of skull base surgery](image-source)


---

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

![Diagram of skull base surgery](image-source)

Our Goal:

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

Approach

Image source: Dr. Kazanzides
Approach

- Photo-acoustic imaging can be accomplished using a **pulsed laser** and an **ultrasound probe**
- Structures respond differently to **different wavelengths**
Sensing and control to reduce model registration uncertainty

**Approach**

- **Preop CT**
- **Fiducials**
- **Anatomical structures**
- **Virtual fixture**
- **Navigation System**
- **Intraop. Imaging**
- **Compute Registration (iterative)**

**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
<table>
<thead>
<tr>
<th>Deliverables (Expected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• More realistic simulation of photo-acoustic imaging based on tracked location of hand-held tool with respect to anatomy using the Matlab package kwave</td>
</tr>
<tr>
<td>• Or: Simple simulation of photo-acoustic imaging based on tracked location of tool (with Neuromate® robot) and probe with respect to anatomy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Deliverables (Maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 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</td>
</tr>
<tr>
<td>• Experiments with a more realistic skull phantom</td>
</tr>
</tbody>
</table>
## Key Dates & Assigned Responsibilities

<table>
<thead>
<tr>
<th></th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to Labs in Hackerman</td>
<td>Hackerman</td>
<td>Hackerman</td>
<td>Hackerman</td>
<td>Hackerman</td>
<td>Hackerman</td>
</tr>
<tr>
<td>Access to robotorium svn repository</td>
<td>Hackerman</td>
<td>Hackerman</td>
<td>Hackerman</td>
<td>Hackerman</td>
<td>Hackerman</td>
</tr>
<tr>
<td>Tutorials for ultrasound/K-wave</td>
<td>Hackerman</td>
<td>Hackerman</td>
<td>Hackerman</td>
<td>Hackerman</td>
<td>Hackerman</td>
</tr>
<tr>
<td>Learn to use navigation system, CISST Library, 3D slicer</td>
<td>Hackerman</td>
<td>Hackerman</td>
<td>Hackerman</td>
<td>Hackerman</td>
<td>Hackerman</td>
</tr>
</tbody>
</table>

### Dependencies

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

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

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
Reading List

(Endonasal) Skullbase Surgery


Photoacoustic Imaging/Modeling Photoacoustic Imaging

