Photoacoustic-based approach to surgical guidance performed with and without a da Vinci robot
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Group 3: Photoacoustic System for Spinal Surgery
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Photoacoustic-based approach to surgical guidance performed with and without a da Vinci robot

- **Main Goal:** Assess safety zones using PA imaging
- **Measured:** distance between “vessels”
- **Applications:** teleoperated surgeries, minimally invasive surgeries
Relevance to Photoacoustic-Guided Spinal Surgery

**My Experiments**
- Human vertebra & whole blood
- Fiber in drill tip

**Paper**
- PA imaging
- Visualization of blood vessels
- Tracking PA signal
- Bovine Tissue
- Rubber tubing
- Da Vinci tool & endoscope
- Teleoperation
Clinical Background

Middle ear nerves and arteries

Middle ear view during mastoidectomy

Superior view of structures surrounding pituitary
PA Background

1. Laser pulse
2. Absorption
3. Thermal expansion
4. Acoustic waves
5. Ultrasound detection
6. Image formation
Technical Approach
Experiments

Model of carotid arteries

Model of uterus
Data Collection

manual

teleoperated
Analysis

Distance = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}

\text{RMS error} = \sqrt{\frac{\sum_{n=1}^{\text{NVS}} \left( \sum_{m=1}^{\text{NVT}_n} D^2 \right)}{\text{TNVT}}}

\text{MAE} = \frac{\sum_{n=1}^{\text{NVS}} \left( \sum_{m=1}^{\text{NVT}_n} |D| \right)}{\text{TNVT}}
Key Results

1. Accuracy of robotic and hand-held image-based vessel separation measurements
2. Accuracy of manual and teleoperated control of optical fiber
3. Discrepancies between laser, beamforming method, and fiber control
4. Variations with different US probe orientations and tissue thicknesses
Key Results
Key Results

- Manual more accurate than teleoperated
- DAS more accurate than SLSC
Main Conclusions

- no definitive trend in the magnitude of error as vessel separation increases
- distances computed from PA data are more precise than da Vinci tracking kinematics
- Submillimeter errors
- SLSC is better for visualization, DAS is better for analysis (based on signal amplitude)
Future Work

- Optimize system for teleoperation
  - Surgical path planning
- Optimize system for different structures (like nerves)
- Use real blood in experiments
- Investigate algorithms that aren’t amplitude based to improve SLSC imaging accuracy
<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td>Detailed Background</td>
<td>No bone</td>
</tr>
<tr>
<td>Detailed Technical Approach</td>
<td>No blood</td>
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<tr>
<td>Versatility of PA method</td>
<td>Simple measurement algorithm</td>
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<tr>
<td>Image Processing</td>
<td>Tool wasn’t visualized</td>
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Citation