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Project Description

- **Goal:** To detect and track tools during surgery (more specifically, needle tips)
- **Our approach:**
  - Use a combination of Ultrasound and 2-D photo images to locate the position of a needle tip with an acoustic element
Paper Selection

- "Needle detection in ultrasound using the spectral properties of the displacement field: a feasibility study", *Proc. SPIE* 9415, Medical Imaging 2015: Image-Guided Procedures, Robotic Interventions, and Modeling, 94150U (March 18, 2015); doi:10.1117/12.2081723; [http://dx.doi.org/10.1117/12.2081723](http://dx.doi.org/10.1117/12.2081723)
Problem Summary

- Ultrasound-guidance is the standard of care for needle procedures
- Clear needle visibility is an issue
- Increased by depth of needle and angles with ultrasound axial direction
Some Other Approaches

- Signal/Image post-processing techniques
- Physical Needle modifications to improve visibility
- Beam formation enhancements
- All require significant change
Methods

- Attempts to resolve needle visibility without any physical changes
- Combine 3 Techniques
  - Displacement Field Estimation
  - Block–based Motion Estimation
  - Spectral Coherency
Displacement Field Estimation

- Optical flow model based on Lucas–Kanade approach
Block-based Motion Estimation

- Motion estimation only done on smaller regions to save on computation

Figure 1: Macro blocks and patches in an ROI.
Spectral Coherency

- Reference block is chosen (tissue or needle)
- Intrinsic body motion produces coherent displacement with respect to reference block
- Intentional movements of the needle also produces coherent displacement with respect to reference block
- $C_{xy}(f)$ is the magnitude squared spectral coherence
- $P_{xx}$, $P_{yy}$, and $P_{xy}$ are the power spectral densities (PSD)

$$C_{xy}(f) = \frac{|P_{xy}(f)|^2}{P_{xx}(f)P_{yy}(f)}$$
Spectral Coherency

- Needle movement coherent to needle block but not tissue block
- High spectral coherency at higher frequencies are needle regions
Experiment Setup

- iU22 ultrasound imaging system with a C5–1 (1–5 MHz) curved array transducer from Philips Ultrasound
- Standard 17 gauge Tuohy epidural needle
- Captured in vivo images of tissue around abdominal aorta for intrinsic body motion data
- Performed needle tracking in an agar based tissue-mimicking phantom
Experiment

- Want to differentiate intrinsic motion from heart beat from:
  - vibration of needle (approx. 1 mm)
  - rotation about the needle shaft (approx. 5 degrees)
  - hand tremor (holding the needle steady)
- Compare results with manual needle localization on B-mode images
Results

- Three motion types compared for a total of 30 images
- Needle shaft localization error for three different motion types captured from an agar phantom (below)

<table>
<thead>
<tr>
<th>Motion Type</th>
<th>$\overline{\Delta l}$</th>
<th>$\sigma_{\Delta l}$</th>
<th>RMS($\Delta l$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tremour</td>
<td>0.9 mm</td>
<td>0.5 mm</td>
<td>1.0 mm</td>
</tr>
<tr>
<td>Vibration</td>
<td>0.6 mm</td>
<td>0.5 mm</td>
<td>0.7 mm</td>
</tr>
<tr>
<td>Rotation</td>
<td>0.5 mm</td>
<td>0.3 mm</td>
<td>0.5 mm</td>
</tr>
</tbody>
</table>

Incorporating an agar phantom to simulate tissue characteristics.
Relevance

- Attempts to solve the same issue that we want to solve
- Provides an alternative viable technique to locate a needle inside a patient during surgery
Assessment

**Pros**
- Does not require additional hardware modifications
- Detects segments of the needle unseen in ultrasound image by human perception
- Low error compared to manual localization

**Cons**
- Did not perform the needle tracking in the human body
- Small sample size
- Requires needle to be in the plane of the Ultrasound image
- Does not run in real time yet