Image-guided Spinal Anesthesia

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Spinal anesthesia

- Epidurals
- Facet blocks
- Spinal blocks
- Spinal taps

- All are done blindly or under fluoroscopic guidance
- For example, it takes 60 patients for a resident to reach competency of 90% in epidural insertion.

**Motivation / Tools / Planning / Guidance**
Epidural needle insertion
Image-based solutions

• Pre-puncture planning
• Real-time guidance
• Some tools may help:
  – Ultrasound: real-time
  – CT: off-line
  – Tracking equipment
  – User interface/software
Prepuncture 2D ultrasound in epidural

Para-median view

Transverse view

Motivation / Tools / Planning / Guidance
Real-time needle guidance using 2D ultrasound

Steep angle: longer needle path
Paramedian view: painful needle insertion through spinae erector muscle
No context

Motivation / Tools / Planning / Guidance

Tran’10
Needle tracking – commercial tools

Examples

**SonixGPS**
Ultrasonix, Richmond, BC, Canada

**eTRAX**
Civco Inc., Kalona, Iowa, US

Sensor-based tracking

Motivation / Tools / Planning / Guidance
3D reslice ultrasound imaging

Transverse view

Motivation / Tools / Planning / Guidance

Rasoulian’10
CT images

- Spine can be segmented manually or automatically
Solution for both planning and guidance

- Acquire images
- Augment images
  - Why augment images:
    - Provide context
    - Improve accuracy
3D Ultrasound reconstruction of spine: with tracker
- Ultrasound probe calibration and tracking

Paramedian view of the ultrasound volume of Lamb fixed in a container

Requires patient tracking

Motivation / Tools / Planning / Guidance

Gill’10
3D Ultrasound reconstruction of spine: with camera on probe

Motivation / Tools / Planning / Guidance

Rafii-Tari’11
3D Ultrasound reconstruction of spine: with camera on probe cont’d

- Online Tracking
- Interactive Interface

Motivation / Tools / Planning / Guidance
3D Ultrasound reconstruction of spine: no tracker

- Speckle tracking

In-plane and out-of-plane motion estimation using speckle tracking

Correct the estimation by registration with CT

Motivation / Tools / Planning / Guidance

Lang’11
3D Ultrasound reconstruction of spine: no tracker

Ground truth  Speckle tracking  Correction with the CT

Lang’11
Ultrasound augmentation with CT: single vertebra

Winter’08 – surface-volume registration

Yan’11 – volume-volume registration

Extract relevant points from CT

Enhance bone surface in ultrasound images

Motivation / Tools / Planning / Guidance

Winter’08, Yan’11
Ultrasound augmentation with CT: multi-vertebrae

Ultrasound acquisition
CT acquisition

Change in the curvature of the spine

Multi-vertebrae registration

Intensity-based registration

Motivation / Tools / Planning / Guidance

Gill’10
Ultrasound augmentation with CT: multi-vertebra

CT segmentation

Surface reconstruction

Multi-vertebrae feature-based registration

Motivation / Tools / Planning / Guidance

Rasoulian’09
Ultrasound augmentation with Atlas

Template

CT₁ → Rigid Registration → Deformable Registration

CT₂ → Rigid Registration → Deformable Registration

CTₙ → Rigid Registration → Deformable Registration

SSM

Eigenvalues

Eigenvectors

Mean Deformation Vector

PCA

Intensity-based registration of the multi-vertebrae atlas to the ultrasound volume

Run-time on GPU: 9 min

Motivation / Tools / Planning / Guidance

Khallaghi’11
Ultrasound augmentation with Atlas

Generation of an unbiased atlas

Feature-based alignment of the single vertebra atlas and ultrasound images

Run-time on Matlab: 5 sec

First four modes of the atlas

Phantom data

in vivo human data

Motivation / Tools / Planning / Guidance

Rasoulian’11
Ultrasound real-time augmentation with CT

- Tracked needle tool, ultrasound transducer and tracker field generator
- Phantom and cadaver study

Accuracy in needle insertion

<table>
<thead>
<tr>
<th>Guidance</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>No guidance</td>
<td>5.77</td>
</tr>
<tr>
<td>Guidance using ultrasound image only</td>
<td>4.87</td>
</tr>
<tr>
<td>Guidance using ultrasound+CT model</td>
<td>0.57</td>
</tr>
</tbody>
</table>

Moore’09, Chen 2010
Open problems

- Real-time guidance with ultrasound augmented by atlas
- Reduce use of tracking tools
- More patient studies
THANK YOU

QUESTION?
References

• [Gill’10] Biomechanically constrained groupwise ultrasound to CT registration of the lumbar spine, Medical Image Analysis 2010.


References

• [Rasoulian’10] Porcine thoracic epidural depth measurement using 3D ultrasound resliced images, CAS 2010.