DBP – Image Guided Prostate Interventions

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Prostate cancer

• One of every 6 men in the U.S. will be diagnosed
• 234,460 new cases in 2006
• Incidence will double by 2015
• ~1 million needle biopsies per year
• ~60,000 brachytherapy procedures per year
Image guided prostatic needle placement

- Diagnosis (core needle biopsy)
- Deliver localized therapy (seeds, injection)
- Imaging research validation (irrefutable ground truth by histopathology of tissue collected from the same location)
Image guidance – MRI

**PROS**
- Sensitivity in detecting soft tissue abnormalities
- Excellent visualization of prostate and normal tissues
- Morphological, functional and molecular imaging

**CONS**
- Expensive
- Limited availability
Image guidance – TRUS

**PROS**
- Reasonable visualization of prostate and normal tissues
- Cheap
- Widely available
- Harmless

**CONS**
- Limited (poor) sensitivity
- Operator dependent
- Invasive
Image guidance – CT

PROS
• Available in RadOnc
• Useful in dose planning

CONS
• Poor sensitivity
• Poor contrast
• Harmful
• Not real time
• Moderately expensive

* Not used outside EBRT & post implant dosimetry
Image guidance – C-arm fluoro

PROS
• Cheap
• Widely available (70% of brachy practitioners have in the OR)

CONS
• Limited soft tissue contrast
• Harmful radiation
• Extremely difficult to use computationally

* Not used outside prostate brachytherapy
Two facts of life

1. Modalities coexist
2. Fusion is necessary
## Project families

<table>
<thead>
<tr>
<th></th>
<th>Trans-rectal</th>
<th>Trans-perineal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MR</strong></td>
<td>Biopsy</td>
<td>Biopsy/Brachy</td>
</tr>
<tr>
<td></td>
<td>(coming: injections)</td>
<td></td>
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<tr>
<td><strong>TRUS</strong></td>
<td>Ablation</td>
<td>Brachytherapy</td>
</tr>
<tr>
<td></td>
<td>(coming: biopsy)</td>
<td></td>
</tr>
</tbody>
</table>
Project #1: Transrectal interventions in closed MRI

Engineering:
The Johns Hopkins University

Clinical:
(1) National Institutes of Health
(2) Princess Margaret Hospital, Toronto
(3) Memorial Sloan Kettering Cancer Center

Funding
NIH/NIBIB 1R01EB002963, PI Fichtinger
(2 more years)
In-scanner robotic assistant

37 patients treated

- Susil et al., Transrectal Prostate Biopsy and Fiducial Marker Placement in a Standard 1.5T MRI Scanner, J Urol. 2006 Jan;175(1):113-20.
Robot close-up

- Rotation knob
- Steerable needle channel
- Needle angle knob
- Hinge
- Rotating rectal sheath w/ imaging coil
- Prostate
- Mount

1cm scale
Results in multiple Ph1 clinical trials

- From concept to trials in 22 months
- 38 biopsies and seed placements
- Accuracy ~3 mm
- No severe adverse events

Example #1

Target (red dot)  Needle void on target  Needle tract on target

Example #2

Krieger et al. IEEE TMBE, 2005
Project #2: Transperineal interventions in closed MRI

Engineering:
Brigham and Women’s Hospital
Johns Hopkins University
Acoustic Medsystems/Burdette Medical

Clinical:
Brigham and Women’s Hospital

Funding
NIH/NCI 1R01CA111288-01, PI Tempany (5 more years)
DoD PC061118, PI, Fischer (2 more years)
In-scanner robotic assistant

DiMaio et al. IEEE BioRob, 2006; Fischer et al. IEEE ICM, 2006

G. Fichtinger, 2006

Engineering Research Center for Computer Integrated Surgical Systems and Technology
Project #3: Transperineal brachytherapy under TRUS

**Engineering:**
Johns Hopkins University
Acoustic Medsystems/Burdette Medical

**Clinical:**
Johns Hopkins University

**Funding**
NIH/NCI 2 R44 CA099374-02, PI Burdette (3 more years)
NIH/NCI 1R21CA120232-01, PI Salcudean (2 more years)
DoD PC 050042, PI Song (1 more year)
NIH/NCI 5R44CA088139-04, PI Burdette (expired)
NIH/NCI 1R43CA099374-01, PI Burdette (expired)
NIH/NCI R01, PI Fichtinger – in submission
(1) TRUS-guided robotic assistant

Physician

Interplant® FDA-approved treatment planning & monitoring computer system

Robot control

Burdette ↔ JHU

G. Fichtinger, 2006
(2) Intra-operative dosimetry & optimization

Initial plan → Update plan → Insert needle

→ US imaging
→ X-ray imaging

Prostate

After batch of needles

During each needle
RUF - Registration of Ultrasound and FLuoro
Project #4: Transrectal HIFU ablation under TRUS

Engineering:
Johns Hopkins University
Acoustic Medsystems/Burdette Medical

Clinical:
Johns Hopkins University

Funding
NIH/NCI 1R41CA106152-01A1, PI Fichtinger (to expire)
TRUS-guided robotic assistant
Perennial image processing themes

- Segmentation in TRUS and MRI
- Deformable registration of the prostate with ultrasound series, with MRI series, and across these
- Multi-dimensional statistical deformable atlas of the prostate, with associated probabilities of cancer and other clinically quantities
- Segmentation, tracking, and measurement of therapeutic substances used in prostate therapies, such as radioactive seeds, injections, etc, in ultrasound, MRI
- Reconstruction of brachytherapy implants in C-arm fluoroscopy
- Segmentation and tracking of surgical tools, such as needles and tissue ablators, in ultrasound and MRI
Current state in clinical systems

- Manual/semi-manual segmentation
- Contour-based registration
- PROS: excellent clinical control, safety
- CONS: extremely time consuming
Example: current state in TRUS segmentation

IMM/PDAF by Abolmaesumi
Example: current state in MRI segmentation

Atlas based segmentation by Vikal

User: Prostate center, expected coil radius

A-priori knowledge: size, shape

Speckle suppression and edge enhancement

Integrate a-priori information

Slice: Central slice
Initial estimate: shape model

Canny edge

A-priori knowledge-based false-edge removal

Fill missing information

Fit closed spline to get final contour estimate for current slice

All slices segmented?

Initial estimate = last final contour

Present to user

No

Yes

User: Prostate center, expected coil radius

A-priori knowledge: size, shape
Perennial issues in system integration

- GUI
  - Old Slicer did not work out
  - Current clinical systems use custom GUI
  - Industry legacy – Burdette Interplant®

- Open source – potential IP issues for industry partner
Questions?

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