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
- ~1 million needle biopsies per year
- ~60,000 brachytherapy procedures per year
- USA incidence will double by 2025
- Add 10% for Canada
- Triple it for Europe
- South-East Asia is coming rapidly
- Multiple by 10 for BPH…

Image guided prostate interventions

- **Diagnosis** (core needle biopsy)
- **Deliver localized therapy** (seeds, injection)
- **Imaging research validation** (there is demand for irrefutable ground truth by histopathology of tissue collected from the same location)

Some facts of life

- **Interventional images are nasty**
  - **Poor signal**
  - **Tool-tissue-imager interaction**
  - **Large inhomogeneities**
  - **Drastic tissue deformation and motion**
- **Modalities coexist**
- **Data fusion is necessary**

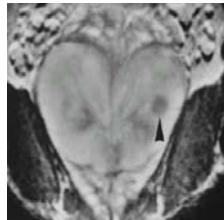## Image guidance – MRI

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

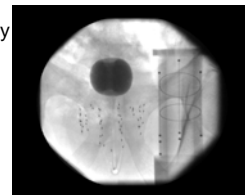* Not used outside EBRT & post implant dosimetry

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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

Current research scope

	Trans-rectal	Trans-perineal
MR	Biopsy/Implants (coming: injections)	Biopsy/Brachy
TRUS	Ablation (coming: biopsy)	Brachytherapy (coming: biopsy, ablation)

Project #1: Transrectal interventions in closed MRI

Engineering:
The Johns Hopkins University

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

Funding
NIH/NIBIB 1R01EB002963, PI Fichtinger
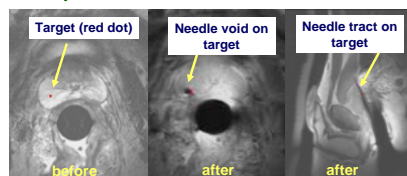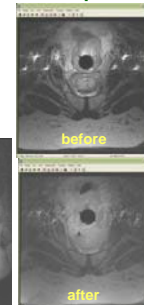(2 more years, to submit competing renewal)

In-scanner robotic assistant

Results in multiple clinical trials

- **From concept to trials in 22 month**
- **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
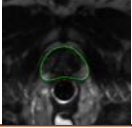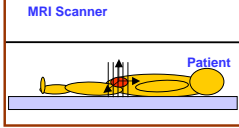
before   after   after

Example #2

before

after

Krieger *et al.* IEEE TMBE, 2005

Problems and needs
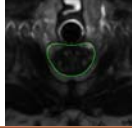
Pre-op planning MRI/MRS - supine
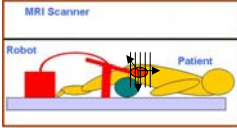
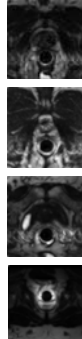Intra-op intervention MRI - prone

Problems of MR prostate registration

- Fusion of pre-op information for improving intra-op execution, under the circumstances:
  - Completely different patient positions → large anatomical misalignment
  - Different imaging parameters
  - Different coils
  - Local deformation and surrounding tissue deformation → significant shape change → Non-rigid registration

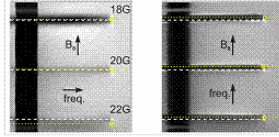## Problems of MR prostate segmentation

- Localize prostate within scanned volume
- Critical: accuracy of segmentation → registration accuracy
- **Challenges**
  - Extreme detail in MRI/MRS → internal structures → too many edges near true boundary
  - No reliable region homogeneity or texture
  - Actual total gland (TG) boundary blends into surrounding tissues
  - Large variation in shapes
  - Variable edge profile within slice and across slices
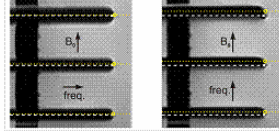 - Variable imaging sequence across datasets

Problems of MR needle/seed/device tracking

Examples of susceptibility artifacts imaged using Single Shot Fast Spin Echo (SSFSE) and Fast Gradient Recalled Echo (FGRE) sequences, with needles perpendicular to B0, and immersed in a NiCl solution. Dashed lines and crosses are actual needle shaft and tip, while dotted lines and circles indicate detected artifact.

*S DiMaio, D Kacher, R Ellis, N Hata, G Zientara, L Panych, G **Fichtinger**, CMC Tempany, R Kikinis, F Jolesz, Needle Artifact Localization in 3T MR Images, Stud Health Technol Inform. 2005;119:120-5.*

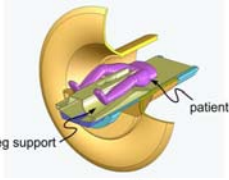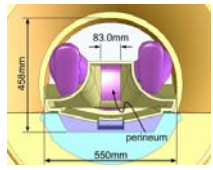## Project #2: Transperineal interventions in closed MRI

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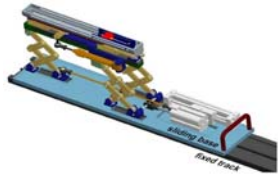Johns Hopkins University
Acoustic Medsystems/Burdette Medical
Clinical:
Brigham and Women's Hospital

In-scanner robotic assistant

Problems and needs

Covered earlier

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)
DoD PC 050170, PI Jain (1 more year)
NIH/NCI 5R44CA088139-04, PI Burdette (expired)
NIH/NCI 1R43CA099374-01, PI Burdette (expired)
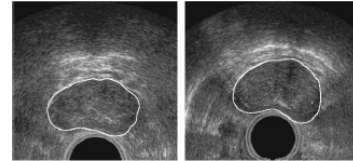NIH/NCI R01, PI Fichtinger – in submission

Approach 1: TRUS-guided robotic assistant

- Max dose to cancer, min dose everywhere else
- Maximize needle/seed placement accuracy w/ robot
- Localize needles and seeds in TRUS
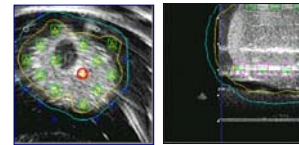- Analyze dose, optimize the remainder of the implant
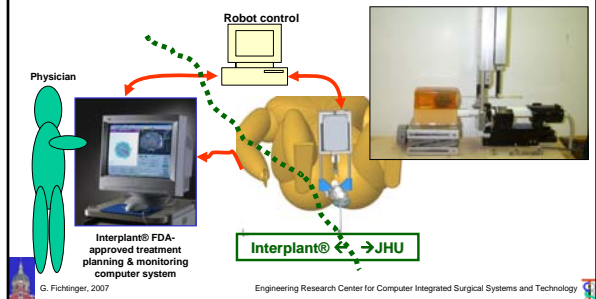
Problems and needs
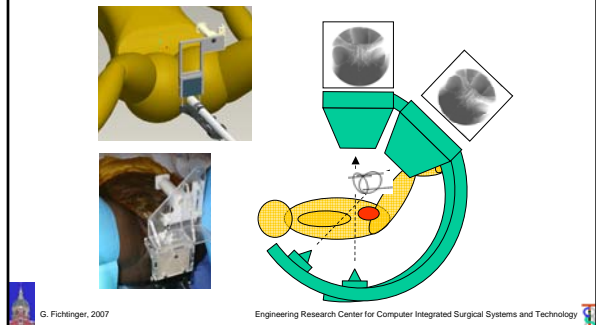
Anatomy segmentation

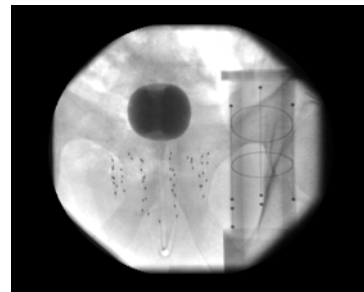**Organ segmentation, tissue tracking, seed & needle tracking**

Approach 2: Registration of TRUS to C-arm

- C-arm fluoro shows seeds, TRUS shows anatomy
- Reconstruct seeds from C-arm and register to TRUS
- Analyze dose, optimize the remainder of the implant

More problems and needs

- Calibration, distortion correction, pose tracking of C-arm
- Bullet proof auto-segmentation of seeds and fiducials

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Project #4: Transrectal HIFU ablation under TRUS

Engineering:
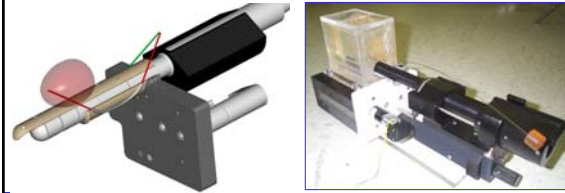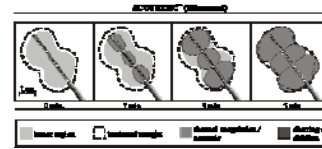Johns Hopkins University
Acoustic Medsystems/Burdette Medical

Clinical:
Johns Hopkins University

Funding
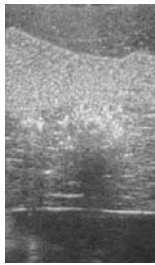NIH/NCI 1R41CA106152-01A1 , PI Fichtinger
(Ph1 to expire, Ph2 to be submitted)

TRUS-guided robotic assistant

More problems and needs

B-mode image	Gross-pathology

Non-invasive monitoring w/ ultrasound

Some perennial image analysis problems

- 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
- Non-invasive temperature monitoring in ultrasound
- Tool & implant tracking in TRUS/MRI
- Tissue motion tracking in TRUS/MRI
- Predictive deformation models….

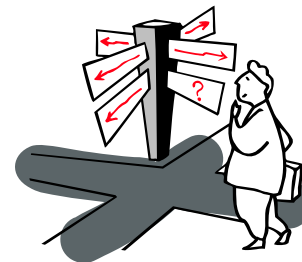## Current state in our clinical systems

- Manual/semi-manual segmentation

- Contour-based registrations

- Legacy GUI & frond-ends

- INFINITE ROOM FOR IMPROVEMENTS

Questions?

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