Evaluation of a Telerobotic System Concept for Real-Time Soft-Tissue Image Guidance During Radiotherapy Delivery

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Conflict of Interest

- Nothing to disclose
Imaging During Beam Delivery

• Existing solutions are limited:
  Radiographic x-ray  Electromagnetic

Real-time marker-less soft-tissue image guidance during beam delivery is an unmet challenge
**Novel Image Guidance Solution**

Telerobotic system enables remote probe control
Telerobotic Imaging

Remote Haptic Interface

Robot
Key Issues

- Remote ultrasound imaging during beam delivery
  - Robotic manipulator design
  - Treatment plan compatibility
  - Performance during radiation exposure
    - Imaging robustness for multiple treatment sites
- Image guidance
  - Temporal calibration and time delay
  - Spatial calibration and accuracy

Details to appear in Medical Physics: Schlosser et al. (2010)
Telerobotic Imaging for Multiple Sites

Image quality remotely maintained over 10 minutes
Image Guidance: Spatial Calibration

Goal: find $\text{im} T_{\text{pr}}$

Variation of planar fit method from Hartov et. al*

Image Guidance: Spatial Calibration

(1) Collect images of plate

(2) Extract points on plane

\[ w_p = w T_{tr} * tr T_{pr} * pr T_{im} * im p \]

(3) Convert to world frame

(4) Optimize planar data fit
Temporal Calibration and System Evaluation: Experimental Method

- Image static target in US phantom
- Vary probe pitch or pressure
- Track target in real-time using NCC
- Use transformation chain to register in world frame
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Temporal Calibration

- **Novel procedure:**
  - Robot pitches US probe w/ sinusoidal motion
  - Static target imaged and tracked using NCC
  - Optical tracker data compared to US pixel data
### Evaluation: Spatial Localization Error

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**Real-time phantom localization error < 1mm**
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Evaluation: Time Lag

- **Experimental method:**
  - Similar to time calibration
  - Robot trajectory (1000Hz) compared to target trajectory in ultrasound sequence

- [Graphs showing comparison of Raw Data and Sinusoid Model]
  - Time [sec]
  - Robot Pitch Encoder
  - World Coordinate

- **Time Lag:** 179ms
Real-Time Guidance at 5 Hz and Sub-millimeter Localization Accuracy
Conclusions

• Remotely-controlled soft-tissue imaging in the treatment vault is feasible for multiple abdominal sites
• Sub-millimeter targeting accuracy with 2D imaging indicates feasibility for accurate real-time 3D ultrasound guidance
• Telerobotic US guidance system could offer non-invasive localization for IGRT that truly reflects soft-tissue anatomy
Questions?

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