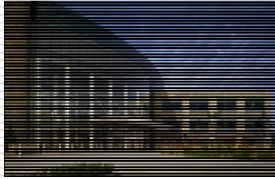


Fluoroscopic Lung Tumor Tracking without Implanted Fiducial Markers

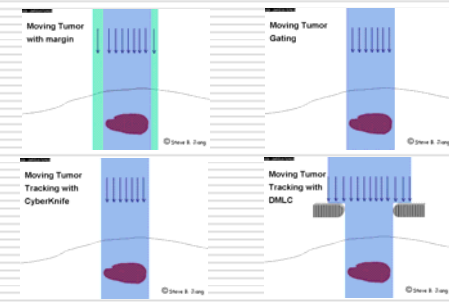


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How Do We Treat a Moving Tumor?

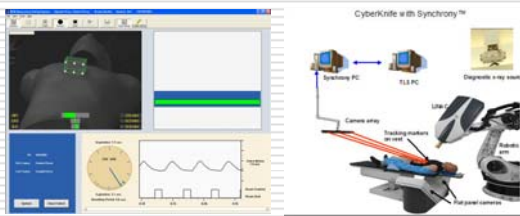


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Tracking based on External Surrogates



Varian RPM

CyberKnife Synchrony

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Shooting A Target by Looking in The Mirror



Image in the mirror
→ Target

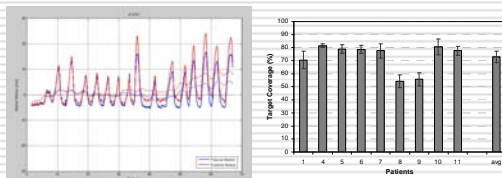
External surrogates
→ Tumor

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Gating based on External Surrogates



Kanoulas, Aslam, Sharp, Berbeco, Nishioka, Shirato, and Jiang
Phys Med Biol 52(17):5443-55456, 2007

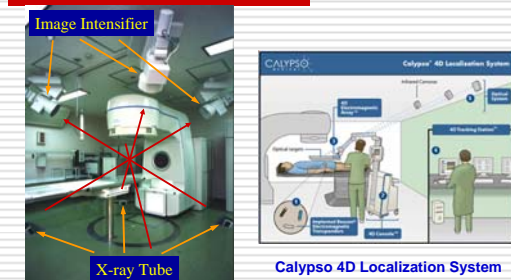
Wu, Zhao, Berbeco, Nishioka, Shirato, Jiang
Phys Med Biol 53(24):7137-7150, 2008

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Tracking using Implanted Fiducial Markers



Mitsubishi/Hokkaido RTRT System

Calypso 4D Localization System

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Implantation of Fiducial Markers

CT guided implantation

US guided implantation

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Direct Lung Tumor Tracking w/o Markers

- **Multiple Template Tracking**
 - ❑ Cui, Dy, Sharp, Alexander, and Jiang, *Phys Med Biol*, 52(20):6229-6242, 2007.
- **Active Shape Model Tracking**
 - ❑ Xu, Hamilton, Schowengerdt, and Jiang, *Phys Med Biol*, 52(17):5277-5293, 2007.
- **Optical Flow Tracking**
 - ❑ Xu, Hamilton, Schowengerdt, Alexander, and Jiang, *Med Phys*, 35(12):5351-9, 2008.

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Indirect Fluoroscopic Tracking

- **Issues with direct tracking**
 - ❑ Directly tracking of the tumor sometimes is impossible due to poor image quality and low target contrast
 - ❑ Common tracking methods used in computer vision often fails since tumor has no color, no texture, and often no clear shape
- **We proposed an indirect tracking approach**
 - ❑ Tracking invisible tumor by tracking visible surrogate features

Lin, Cervino, Tang, Vasconcelos, and Jiang, *Phys Med Biol* 54(4): 981-992, 2009.

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Indirect Fluoroscopic Tracking

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Diaphragm as an Internal Surrogate

$$y_0 = a + \sum b_i s_i$$

Mean error ~ 1 mm
Maximum error (e95) ~ 2 mm

Cervino, Chao, Sandhu, and Jiang
Phys Med Biol 54(11): 3529-3541, 2009

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Diaphragm Does Not Always Work

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Future work: building a comprehensive tracking system

X-ray (Only when necessary)

Surface Tracking Camera (Always on)

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Tumor Tracking during Arc Therapy

Freedom to treat

Courtesy of Elekta

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Reconstruct Tumor Trajectory from CBCT Projections

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Tumor Tracking in Rotational Geometry

- Reference templates
 - ☐ DRRs generated for each phase of 4DCT
- Volume of Interest (VOI)
 - ☐ VOI generated for 4DCT
 - ☐ VOI projected, defining an ROI in each DRR and CBCT projection

Reference Templates CBCT Projections

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Phase Binned Trajectory Reconstruction

- Draw lines from each source position to each tumor position

- Phase bin each line based on breathing signal

SI (cm)

AP (cm)

LR (cm)

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Preliminary Results: Digital Phantom (NCAT)

True Position

Algorithm Output

Tumor Position (mm)

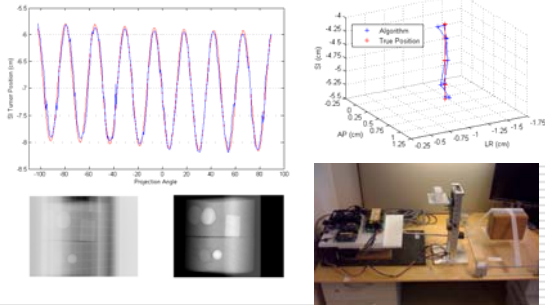
Projection Angle

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Preliminary Results: Physical Phantom



Acknowledgement

- John Lewis
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