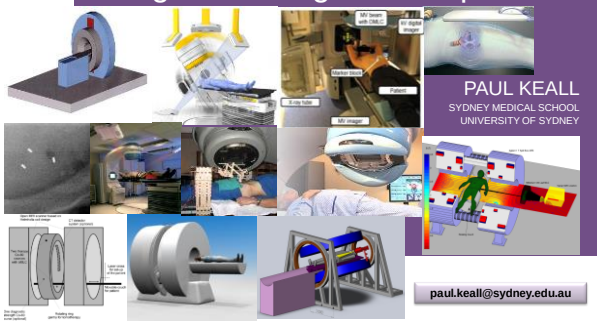
A Review of Present and Near-Future Methods for Real-Time Target Tracking and Adaptation



PAUL KEALL
SYDNEY MEDICAL SCHOOL
UNIVERSITY OF SYDNEY

paul.keall@sydney.edu.au

Disclosures

- **Patents:** Awarded and pending
- **Licenses:** Nano-X, Respiratory Innovations, Standard Imaging, Varian
- **Grants:** Philips (Co-Investigator), Varian (Co-I)
- **Ownership:** Cancer Research Innovations, Nano-X, Respiratory Innovations

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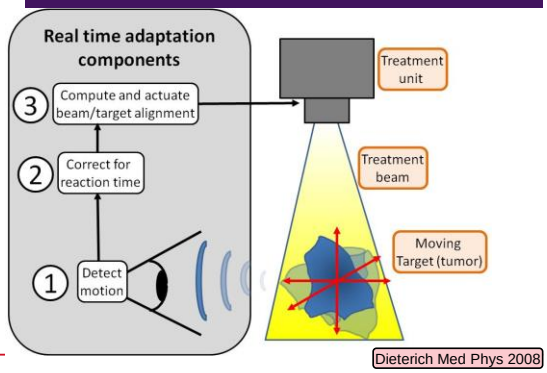
Introduction

Real-Time Target Tracking and Adaptation Components



Dieterich Med Phys 2008

Real-Time Target Tracking Technologies

What is your real-time target tracking feature wish list?

What is your real-time target tracking feature wish list?

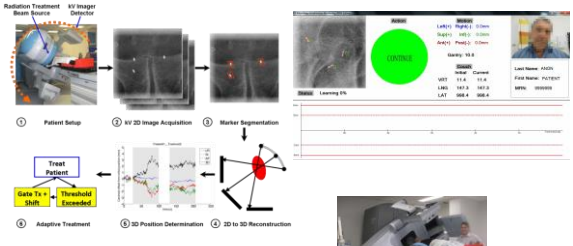
- Volumetric
- High spatial resolution
- High temporal resolution
- High fidelity
- Can transfer planning contour & dose information to & from
- Low latency
- No interference with delivery system
- Non-invasive
- No imaging dose
- Can optimize and compute dose on
- Reduces treatment time
- Cheap with low operational costs
- …

Real-Time Target Tracking Technologies

Present
- X-ray & respiratory (Cyberknife, Vero, Linac)
- Electromagnetic (Calypso, RayPilot)
- MRI-Guided (ViewRay, …)

Near future
- Ultrasound
- Markerless X-ray kV, MV, 4D fluoro

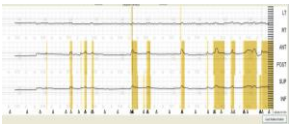
Real-time 3D imaging guidance on a linac

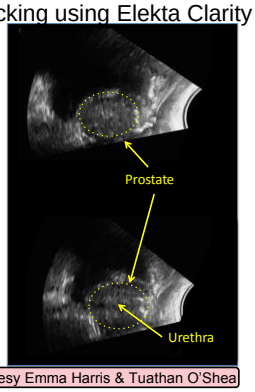


Treatment 1: 26 Sept 2014

SBRT Tx 1: 5 June 2015

Real-time Ultrasound Guidance: Prostate tracking using Elekta Clarity

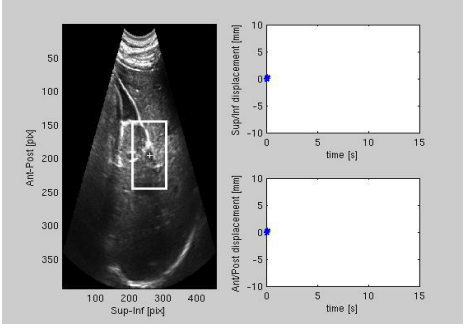




Elekta Clarity Autoscan™: Gating response interface received FDA Clearance Nov 2014

Courtesy Emma Harris & Tuathan O'Shea

Real-time Ultrasound Liver Guidance

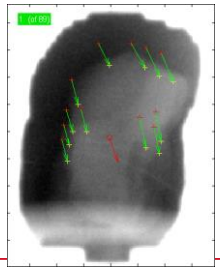


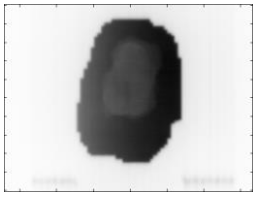
Potential for robust tracking of liver tissue during therapy – O'Shea et al. MO-DE-210-5

Courtesy Emma Harris & Tuathan O'Shea

Real-time markerless guidance (MV)

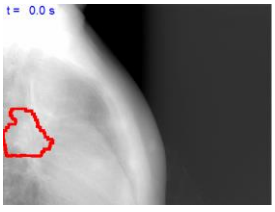
- Less contrast, challenges with beam modulation
- Cheapest, in BEV



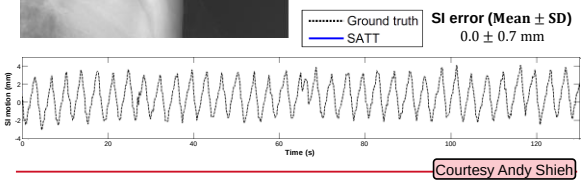


Courtesy Ross Berbeco & Joerg Rottmann

Real-time markerless guidance (kV)

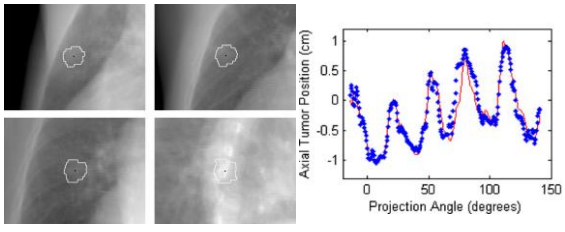


- Class of algorithms w/without priors, including digital tomosynthesis



Courtesy Andy Shieh

Real-time '4D' fluoroscopy



Lewis PMB 2010

Real-Time Adaptation Technologies

What is your real-time adaptation wish list?

What is your real-time adaptation wish list?

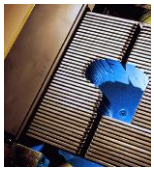
- Integrates all sources of imaging information
- Integrates all sources of uncertainty
- Optimizes in real-time using all available degrees of freedom
- Modifies delivery appropriately
- Responds instantaneously

Real-time Adaptation Systems

Robotic linac head
CyberKnife
Synchrony, Accuray
Clinical 2004

Gimbaled linac
Vero/Mitsubishi
Clinical 2011

MLC adaptation
Clinical 2013
Smallest
Lightest
6 DoF
Deformation



Robotic couch
Clinical ?

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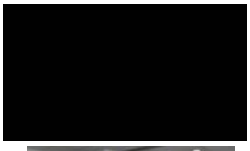
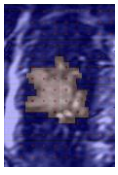
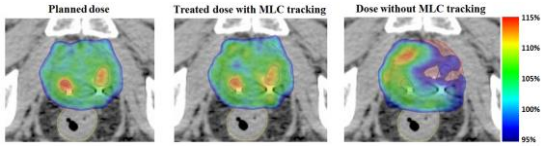
Clinical MLC tracking



Treatment 1: 28 Nov 2013 | SBRT Tx 1: 21 Feb 2015

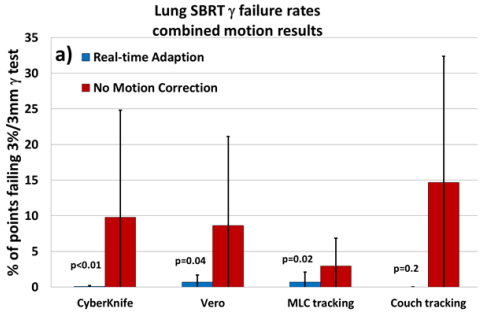
Dose With and Without MLC Tracking



Red = PTV

Colvill IJROBP 2015

Real-time adaption vs nothing (current standard of care)



Courtesy Emma Colvill

Summary

Summary

- Many real-time target tracking and adaptation technologies are available
- Several barriers to widespread uptake
- Tipping point will be availability on standard linacs → clinical routine

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