Real Time Tumor Motion Tracking with CyberKnife

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Learning objectives

- Review the principles of real-time tumor motion tracking with Synchrony
- Discuss clinical applications
- Discuss tracking accuracy
- □ Compare it to other implementation

Disclosure

 Research support and Pilot program evaluation agreement, Accuray Inc Sunnyvale, CA

The CyberKnife system



Imaging and tracking system



Synchrony Motion Tracking



Automatic model



Dataset Acquisition

- Phase triggered dataset acquisition
 - First image mid respiratory phase
 - 9 random pairs
 - Analysis of current model before triggering 3 additional image pairs at the required respiratory phase
- □ Easier to get an optimal model less user dependent
 - > 85% coverage
 - Well distributed model points
 - Low correlation error

Movie Mode (video)



Comet graphs (video)



Video courtesy of Accuray

Internal target position

The internal target position can be extracted based on gold markers or large/ dense tumors visible on 2 cameras or just 1 camera



Tumor visible on 2 cameras: 2-views



Tumor visible on 1 camera: 1-view A or 1-vew B



1-view tracking

- □ Tumors visible in only 1 projection image
- □ The component of motion in the image plane is tracked
- □ Partial ITV expansion in the the un-tracked direction
- Sup-Inf motion is tracked



Example of target visible on 1-view

□ With 1-view tracking is possible to track relatively small targets





GTV dimensions = $9 \times 9 \times 9 \text{ mm}^3$

Tracking options for Lung



Tracking accuracy



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PHYSICS CONTRIBUTION

CLINICAL ACCURACY OF THE RESPIRATORY TUMOR TRACKING SYSTEM OF THE CYBERKNIFE: ASSESSMENT BY ANALYSIS OF LOG FILES

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- Calculated the difference between predicted and actual target position
- Mean error < 0.3 mm</p>
- Intra-fraction error <2.5 mm for respiratory amplitudes up to 2 cm</p>
- Tracking compensated for both intra-fraction motion and for interfraction baselines shifts
- Tracking accuracy in phantoms < 0.95 mm</p>

Tracking with the Vero Gimbals System



- Tracking based on IR breathing signal and correlation model
- Gimbals system Pan & tilt motion of the treatment beam
- It can quickly steer beam to track tumor motion
- Total system latency is 40 ms
- Marker & marker-less Dynamic Tumor tracking & Gating





- CyberKnife Synchrony enables to synchronize respiratoryinduced target motion with radiation delivery
- Correlation model between the position of the internal target and the position of external markers (LED)
- The robot position is continuously re-adjusted to follow the moving target
- □ Marker & marker-less dynamic tracking
- □ Clinically implemented for over 10 years
- □ Tracking accuracy in phantoms < 0.95 mm

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UCSF CyberKnife team

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