Update on TG 147: QA for non-radiographic localization and positioning systems

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Twyla Willoughby
Thank-You

Joerg Lehmann, Ph.D.: TG Co-Chair
Radiological Associates of Sacramento

José A. Bencomo, Ph.D.
US Oncology

Shirish K. Jani, Ph.D.
Sharp Metropolitan Medical Campus

Lakshmi Santanam, Ph.D.
Washington University

Anil Sethi, Ph.D.
Loyola University Medical Center

Timothy D. Solberg, Ph.D.
UT Southwestern Medical Center

Wolfgang A. Tomé, Ph.D.
University of Wisconsin
School of Medicine and Public Health

Tim Waldron, M.S.
University of Iowa
IGRT

- Ultrasound: Soft tissue alignment – mostly prostate
- Orthogonal MV x-rays: Bony anatomy or implanted markers
- Orthogonal kV x-rays: Bony anatomy or implanted markers
- Cone-beam CT: image quality may be an issue
- MV CT: Image quality may be a concern
- In room CT: Good image quality not exactly same treatment position
- **Other:** Video, RF, and laser alignment systems
Disclaimer

- Task Group Report has NOT been approved as of yet.

- Projected publication date: Late 2009/Early 2010
What is Optical Tracking?

- Optical tracking is a means of determining in **real-time** the position of an object by tracking the positions of either active or passive infrared markers attached to the object. The position of the point of reflection is determined using a camera system.
Stereo Correspondence
How Does it Work?

Optical Tracking

Meeks RSNA 2002
Calibration to Isocenter
Equation can be solved numerically using optimization algorithms (Hook and Jeeves, etc.), or closed form solutions such as single value decomposition or Horn’s method (quaternions)
Infrared Camera Alignments


Other Alignment Systems (VisionRT)
Patterned Light Projection Stereo Example
VisionRT Ltd., ALIGNRT

• RT Vision sensor system arranged in pods, each is capable of stereo “vision”.

• A pod contains 1 stereo pair of cameras and a speckle pattern projector.

• A texture camera, white flash, and speckle flash projector are also present.
C-Rad Sentinel™  LAP: Galaxy
Laser Line Projection Methods

For a surface displaced normally from the reference by \( z \), the reflected laser spot \( P(x, \theta) \) now projects to a different pixel \( I(x', y') \) in the image.

Laser Line Projection Methods

Spot deflection, $\Delta I$ is related to the height change $z$ and the overall geometry, and can be computed so long as the incident angles and camera-interferometer geometry are well known.

$$\Delta I = \frac{FS \cos^2 \theta_i}{D - S \sin \theta_i \cos \theta_i}$$

Here $F$ is the camera focal length, $S$ is the separation of laser source and camera, and $D$ is height above the reference plane.


Waldron, T. Univ of Iowa
Video and Laser References


Super Dimension: RF guided Bronchoscopy

Transponder tip
Ascension Technology products use RF sensors to track the position and orientation in real-time of instruments including ultrasound probes. Tracking accuracy is unaffected by the nearby presence of conductive metals including aluminum, titanium and stainless steel 300
Calypso Medical System
RF References


Evaluation of Collision Space

Calypso System during Commissioning
Calibration to Isocenter
End to End test

1. Scan of Phantom
2. Treatment Plan of Phantom
3. Localization of Phantom
4. Orthogonal Films of Central Target
5. Analysis
Localization on Treatment Planning System: IR Example 1
Setup of at Treatment Machine using Optical Guidance: Example 1
Resulting Film: Measure of Total Accuracy of System

Predicted error:
- Z-Pixel Size = 1.25mm
- X-Pixel Size = 0.703 mm
- Y-Pixel Size = 0.703 mm
- Predicted Error = 1.59mm

Results:
- Z: 0.49 mm to T
- X: 0.35 mm to A
- Y: 0.50 mm High
- Overall error = 0.789mm

Tome RSNA 2002
Example 2: Phantom for Calypso system
(Treatment plan of Implanted target)
Example 2: Phantom for Calypso system
Reproducibility

Meeks, AAPM 2000
Test of Localization: Introduce offsets and measure localization system offset
Phantom

Beacon® Phantom

3X 1D Stages

Validation Digitizer
Tracking Accuracy Measurements

Phantom Trajectory vs. System Tracking

[Graph showing comparison between tracked and phantom trajectories over time with amplitude on the y-axis and time on the x-axis.]
### Daily QA

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Collision interlocks</td>
<td>Pass</td>
</tr>
<tr>
<td>Localization accuracy</td>
<td>Phantom at isocenter</td>
<td></td>
</tr>
</tbody>
</table>

### Installation

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Collision space</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Linac interference with localization system</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Localization system interference with radiation delivery system</td>
<td></td>
</tr>
<tr>
<td>Range of Localization</td>
<td>Move table while localizing to maximum range</td>
<td></td>
</tr>
<tr>
<td>Range of Tracking</td>
<td>Move table while tracking to maximum range</td>
<td></td>
</tr>
<tr>
<td>Tracking Rage</td>
<td></td>
<td>Per manufacturer specification</td>
</tr>
</tbody>
</table>
### Test and Method

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Machine interface: Gating termination, table auto-translation,</td>
<td></td>
</tr>
<tr>
<td>Laser localization system QA</td>
<td>Following Linac QA TG reports</td>
<td></td>
</tr>
<tr>
<td>Isocenter QA</td>
<td>Following Linac QA TG reports</td>
<td>Machine spec.</td>
</tr>
<tr>
<td>Localization accuracy</td>
<td>System end-to-end test (with CT scan, treatment plan and orthogonal portal films)</td>
<td></td>
</tr>
<tr>
<td>Tracking accuracy over clinical range: at clinical rate of motion</td>
<td>Motion table</td>
<td></td>
</tr>
<tr>
<td>Data transfer</td>
<td>Test patient transferred from planning system to localization system</td>
<td>Data transmitted correctly</td>
</tr>
<tr>
<td>Accuracy in tracking up to 10cm from isocenter</td>
<td>Shift phantom from isocenter</td>
<td></td>
</tr>
</tbody>
</table>
### Annually (in addition to Monthly)

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Electrical System: Test/reset buttons &amp; breakers are functional</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>Emergency off buttons are functional</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>System mounting brackets (all cameras are secure)</td>
<td>Pass</td>
</tr>
<tr>
<td>Drift in measured isocenter over time of use</td>
<td>Alignment vs. time</td>
<td></td>
</tr>
<tr>
<td>Reproducibility</td>
<td>Repeat system alignment at least 10 times to localize a fixed phantom</td>
<td></td>
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<tr>
<td>System latency and tracking timing</td>
<td>Accurate motion table</td>
<td></td>
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References

