Patient Specific 3D Surfaces for Interactive Medical Planning and Training

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Outline

• Background and Motivation
• Related work;
  • Surface Scanning – Technology
  • 3DRTT
• Proposed Scanning System
  • Configuration Scenarios
  • Accuracy Assessment
• Data Processing and Optimization
Background (1)

• Radiotherapy is a complex procedure for cancer treatment commonly administered in conjunction with other forms of cancer management like surgery and chemotherapy.

• 50-60% of cancer patients are treated with radiation at different stages (www.radiologyinfo.org)
Background (2)

- External beam radiotherapy systems:
  - X-Ray Therapy (XRT)
  - Proton Therapy (PT)
Motivation (1)

- Accurately predicting and preventing collisions among different hardware system components and the patient to avoid re-planning.

- Hardware Collisions
- Beam intersection with external objects

- Planning
  - Calibration of radiation sources
  - Planning of patient procedures
  - Calculation of patient dose (dosimetrists)

- Beam Parameters:
  - Gantry = 245°
  - Couch = 350°
  - Collimator = 0°
  - VRT = 10.0
  - LAT = 0.0
  - LNG = 60
Motivation (2)

• Simulation tool for realistic representation of the treatment room with as much detail and resolution as possible

• Interactivity for configuration and visualization of different systems components (table, collimator, devices, beams etc...)

• Simple, web-enabled interface to facilitate collaboration and reduce overhead and cognitive load

• Uses:
  • Clinical – planning phase
  • Teaching
  • Patient education
Related Work – 3DRTT

• X-Ray Therapy Simulator (2007-2014)

• Accurate hardware models but
• **Generic patient model**

http://3drtt.org/
Related Work – 3D scanning

• We want:
  • Real-time 3D patient models
  &
  • Inexpensive/reconfigurable solution

• Hardware and Software ...

<table>
<thead>
<tr>
<th>Name</th>
<th>Operating range</th>
<th>Frame Speed</th>
<th>Accuracy</th>
<th>Scanner Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinect ($250)</td>
<td>[0.4, 4] m*</td>
<td>30Hz</td>
<td>3mm @ 1.0m#</td>
<td>NCA Structured Light</td>
</tr>
<tr>
<td>Kinect v2 ($200)</td>
<td>[0.5, 4.5] m*</td>
<td>30Hz</td>
<td>1mm @ 1m#</td>
<td>NCA Time of Flight</td>
</tr>
<tr>
<td>Sense ($500)</td>
<td>[0.4, 3.5] m*</td>
<td>30Hz</td>
<td>1mm @ 0.5m$</td>
<td>NCA Structured Light</td>
</tr>
<tr>
<td>SCANIFY ($1500)</td>
<td>[0.35, 0.45] m</td>
<td>10Hz</td>
<td>350 microns$</td>
<td>NCP Stereoscopic and photometric</td>
</tr>
<tr>
<td>David SLS-2 ($3000)</td>
<td>(0.4, ∞) m</td>
<td>30Hz</td>
<td>&lt;1% of length$</td>
<td>NCA Structured Light</td>
</tr>
</tbody>
</table>

* Accuracy is reduced with distance.
$ Advertised accuracy
# Reduced field-of-view. See section 3.3.
Proposed Scanning System

• Accuracy of MK vs MKv2:
Proposed Scanning System

• Based on Microsoft Kinect (v2)
• Configuration scenarios:
IR Camera Calibration

• Calibration procedure (Kahlesz et al. [2007].)

• In practice must be done one time – since the treatment system is based on optical precision tables.
Data Processing and Optimization (1)

• Polygonal Mesh Optimization

  • Point clouds are processed using the Poisson Surface Reconstruction (PSR) algorithm [Kazdan and Hoppe 2013]

  • We remove inaccurate vertices by assigning a quality value based on the Hausdorff distance [Cignoni et al. 1998] between points on the mesh and points on the original point cloud.
Data Processing and Optimization (2)

• Compression - X3D Binary Format
  
  • We reduce the file size of the model by switching to the X3D compressed binary format (X3Db) [X3DB 2015] (80% reduction => 3 MB S-reps).
  
  • Improve initial 3D models download time
  
  • Potential for 3D libraries of complex cases/ treatment scenarios
Data Processing and Optimization (3)

- Decimation vs. Accuracy – Tradeoffs
  - Tested patient S-rep that was 10.568 MB in size containing 96,388 polygons
  - Decimated iteratively to 80%, 60%, 40%, 20%, and 10% of the original number of polygons

- Conclusion:
  - 5-10 scans depending on the length and width of the patient, but could still be automated, quick, and offer a maximum error as low as 10.2 mm.
Results

Proton Therapy with Real Patient S-reps

X-Ray Therapy with Real Patient S-reps
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http://3drtt/org

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