Automated Plan Quality Check with Scripting

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Outline

• Introduction - BSW
• Automation in Treatment planning
• Eclipse Scripting API
• Script development
• Commissioning and testing
• Clinical implementation
Radiation Oncology: BSW

• Main clinic located at Temple, TX
  – Novalis Tx, Clinac 2100 C/D, Nucletron HDR unit
• Satellite clinics
  – Killeen: Clinac 2100 C/D
  – Waco: Truebeam, Varisource HDR unit
  – Waxahachie: Truebeam, Varisource HDR unit
  – Duncanville: Clinac 2100
• Future satellite clinics
  – Round rock (~ 2017 year end)
  – College station (~ 2016 year end)
Radiation Oncology @ BSW

• Physician team
  – 9 Physicians
  – 6 Physician residents

• Physics team
  – 9 Physicists
  – 6 Dosimetrists
  – 1 Dosimetry student
  – 4 Physics residents
Automation in Treatment Planning

• Benefits of Automation
  – Improved efficiency
  – Reduced human error

• Components of treatment planning
  – Contouring
  – Beam arrangement and apertures
  – Optimization
  – Dose calculation
  – Constraints check
  – Plan documentation/printing
Treatment Workflow

CT sim → CT import, Fusion and normal contours → Physician contours → Treatment plan generation

IMRT QA

Plan printing (documentation) → Physics Initial chart check → Treatment delivery

Physician review & approval

Baylor Scott & White Health
SRS SBRT Treatment Workflow

1. CT sim
2. CT import, Fusion and normal contours
3. Physician contours
4. Treatment plan generation
5. Treatment delivery
6. Plan printing (documentation)
7. Physics Initial chart check
8. VSIM
9. IMRT QA
10. Physics precheck
11. Physician review & approval
Eclipse Scripting API

• The Eclipse Scripting API (application programming interface) allows developers to write C#.NET scripts to access treatment planning information in Eclipse.

• The scripts can be integrated into the Eclipse user interface, or they can be run as stand-alone executables.

• Scripts cannot write or change anything in the plan. READ only
Scripting in Eclipse

- Available tool – Eclipse v.11 and up
- https://variandeveloper.codeplex.com
Clinical Implementation

Started using for SBRT and SRS plans and expanded to all treatment plans at our clinic

Consider SBRT lung plan case

2 Rapid Arcs 9 non co-planar beams
<table>
<thead>
<tr>
<th>Serial Tissue</th>
<th>Volume</th>
<th>Volume Max (Gy)</th>
<th>Max Point Dose (Gy)**</th>
<th>Endpoint (≥Grade 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optic Pathway</td>
<td>&lt;0.2 cc</td>
<td>19.2 Gy</td>
<td>21.2 Gy</td>
<td>neuritis</td>
</tr>
<tr>
<td>Cochlea</td>
<td></td>
<td>18 Gy</td>
<td></td>
<td>hearing loss</td>
</tr>
<tr>
<td>Brainstem (not medulla)</td>
<td>&lt;0.5 cc</td>
<td>20.8 Gy</td>
<td>27.2 Gy</td>
<td>cranial neuropathy</td>
</tr>
<tr>
<td>Spinal Cord and medulla</td>
<td>&lt;0.35 cc</td>
<td>18 Gy</td>
<td>25.6 Gy</td>
<td>myelitis</td>
</tr>
<tr>
<td>Spinal Cord Subvolume (5-6 mm above and below level treated per Ryu)</td>
<td>&lt;10% of subvolume</td>
<td>18 Gy</td>
<td>25.6 Gy</td>
<td>myelitis</td>
</tr>
<tr>
<td>Cauda Equina</td>
<td>&lt;5 cc</td>
<td>26 Gy</td>
<td>28.8 Gy</td>
<td>neuritis</td>
</tr>
<tr>
<td>Sacral Plexus</td>
<td>&lt;5 cc</td>
<td>26 Gy</td>
<td>28 Gy</td>
<td>neuropathy</td>
</tr>
<tr>
<td>Esophagus*</td>
<td>&lt;5 cc</td>
<td>18.8 Gy</td>
<td>30 Gy</td>
<td>stenosis/fistula</td>
</tr>
<tr>
<td>Brachial Plexus</td>
<td>&lt;3 cc</td>
<td>24.8 Gy</td>
<td>29.6 Gy</td>
<td>neuropathy</td>
</tr>
<tr>
<td>Heart/Pericardium</td>
<td>&lt;15 cc</td>
<td>28 Gy</td>
<td>34 Gy</td>
<td>pericarditis</td>
</tr>
<tr>
<td>Great vessels</td>
<td>&lt;10 cc</td>
<td>43 Gy</td>
<td>49 Gy</td>
<td>aneurysm</td>
</tr>
<tr>
<td>Trachea and Large Bronchus*</td>
<td>&lt;5 cc</td>
<td>28.8 Gy</td>
<td>34.8 Gy</td>
<td>stenosis/fistula</td>
</tr>
<tr>
<td>Bronchus- smaller airways</td>
<td>&lt;0.5 cc</td>
<td>20 Gy</td>
<td>28 Gy</td>
<td>stenosis with atelectasis</td>
</tr>
<tr>
<td>Rib</td>
<td>&lt;5 cc</td>
<td>43 Gy</td>
<td>54 Gy</td>
<td>Pain or fracture</td>
</tr>
<tr>
<td>Skin</td>
<td>&lt;10 cc</td>
<td>33.6 Gy</td>
<td>36 Gy</td>
<td>ulceration</td>
</tr>
<tr>
<td>Stomach</td>
<td>&lt;5 cc</td>
<td>25 Gy</td>
<td>33.2 Gy</td>
<td>ulceration/fistula</td>
</tr>
<tr>
<td>Bile duct</td>
<td></td>
<td>38.4 Gy</td>
<td></td>
<td>stenosis</td>
</tr>
<tr>
<td>Duodenum*</td>
<td>&lt;5 cc</td>
<td>17.2 Gy</td>
<td>24.4 Gy</td>
<td>ulceration</td>
</tr>
<tr>
<td>Jejunum/Ileum*</td>
<td>&lt;30 cc</td>
<td>18.8 Gy</td>
<td>30 Gy</td>
<td>enteritis/obstruction</td>
</tr>
<tr>
<td>Colon*</td>
<td>&lt;20 cc</td>
<td>26 Gy</td>
<td>32 Gy</td>
<td>colitis/fistula</td>
</tr>
<tr>
<td>Rectum*</td>
<td>&lt;20 cc</td>
<td>30 Gy</td>
<td>37.5 Gy</td>
<td>proctitis/fistula</td>
</tr>
<tr>
<td>Ureter</td>
<td></td>
<td>43 Gy</td>
<td></td>
<td>stenosis</td>
</tr>
</tbody>
</table>
Treatment plan generation

Planning requirements
- Target (PTV) coverage criteria
- Normal structures constraints
- Conformity constraints

Optimization
- Optimization objectives

Check if constraints are met

Non-coplanar beams
- Weights
- Angles
- Apertures
Data lookup from DVH
## Dose constraint spreadsheet

### Lung SBRT dose constraints

<table>
<thead>
<tr>
<th>Patient:</th>
<th>MR #:</th>
<th>Dose:</th>
<th>Site:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>XXXX</td>
<td>123</td>
<td>5000</td>
<td>ALL</td>
<td>6/14/2016</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PTV (cc)</th>
<th>minor deviation</th>
<th>major deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>V100 % (cc)</td>
<td>0.00</td>
<td>1.3</td>
</tr>
<tr>
<td>V50% (cc)</td>
<td>0.00</td>
<td>4.4</td>
</tr>
<tr>
<td>D2cm (%Rx)</td>
<td>0.00</td>
<td>56.7 %</td>
</tr>
<tr>
<td>V20Gy (%lung)</td>
<td>0.00</td>
<td>10.0 %</td>
</tr>
</tbody>
</table>

### Lung SBRT dose constraints

**Legend:**
- Dose constraint: Pass, Fail
- Volume Constraint: At limit

#### RT01 095

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Dose (Gy)</th>
<th>Plan Max (Gy) or (cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinal cord</td>
<td>0.035</td>
<td>26</td>
</tr>
<tr>
<td>Esophagus</td>
<td>0.035</td>
<td>36</td>
</tr>
<tr>
<td>Brachial Plexus</td>
<td>0.035</td>
<td>27.2</td>
</tr>
<tr>
<td>Heart/Pericardium</td>
<td>0.035</td>
<td>34</td>
</tr>
<tr>
<td>Great vessels</td>
<td>0.035</td>
<td>49</td>
</tr>
<tr>
<td>Trachea</td>
<td>0.035</td>
<td>34.8</td>
</tr>
<tr>
<td>Skin</td>
<td>0.035</td>
<td>38</td>
</tr>
<tr>
<td>Stomach</td>
<td>0.035</td>
<td>27.2</td>
</tr>
<tr>
<td>Rib**</td>
<td>0.035</td>
<td>46</td>
</tr>
</tbody>
</table>

*Avoid circumferential irradiation:*
**Rib limit may be exceeded if rib structure lies within PTV

#### Timmerman 2009

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Dose (Gy)</th>
<th>Plan Max (Gy) or (cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinal cord</td>
<td>0.035</td>
<td>25.6</td>
</tr>
<tr>
<td>Esophagus</td>
<td>0.035</td>
<td>38</td>
</tr>
<tr>
<td>Brachial Plexus</td>
<td>0.035</td>
<td>27.2</td>
</tr>
<tr>
<td>Heart/Pericardium</td>
<td>0.035</td>
<td>34</td>
</tr>
<tr>
<td>Great vessels</td>
<td>0.035</td>
<td>49</td>
</tr>
<tr>
<td>Trachea and Large Bronchus</td>
<td>0.035</td>
<td>34.8</td>
</tr>
<tr>
<td>Skin</td>
<td>0.035</td>
<td>38</td>
</tr>
</tbody>
</table>

### File link

[Link to file]
TIME - Measurement Metric

- DVH data look up
- Enter numbers in spreadsheet or
- Verify directly against constraints

To achieve a desired plan (e.g. SBRT Lung)
~ 3 iterations = ~ 24 min in DVH data look up

Can we get this done faster?

YES
Use of Eclipse Scripts
# SBRT SRS Treatment Plans

- **SBRT plans**
  - Lung
  - Spine
  - Pancreas
  - Liver
  - Rectum
- **SRS plans**
  - Brain mets
  - Acoustic Neuroma

### 24 min of DVH data look up

- **122 plans × 24 min = 2928 min**

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Feb</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Mar</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Apr</td>
<td>18</td>
<td>9</td>
</tr>
<tr>
<td>May</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>Jun</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Jul</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Aug</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Sep</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Oct</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Nov</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Dec</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>122</strong></td>
<td><strong>60</strong></td>
</tr>
</tbody>
</table>

**122 × 3 × 0.5 min = 183 min**
Commissioning of Scripts

- Critical testing was conducted
  - Patient information
  - Prescription
  - Auto listing of contours
  - Naming conventions
  - DVH data look up
  - Conformity criteria interpolation
  - Constraint type look up
  - Color coding (pass fail marginal-pass)
  - For different fractionations
  - Point dose vs. pixel dose
  - Constraint reference information
  - Custom constraints
  - Etc
  - Tested on multiple plans (diff sites, fractionations, and patients)
Script Based Plan Constraints Check

• All types of plans
  – 3D, IMRT, Rapid Arcs, SBRT, SRS, etc
  – Physician specific dose constraints tables
  – References for dose constraints
  – Customizable constraints tables
  – PDF print of the constraints verification table
SRS SBRT Treatment Workflow

CT sim → CT import, Fusion and normal contours → Physician contours → Treatment plan generation

IMRT QA → VSIM → Physician review & approval → Physics precheck

Plan printing (documentation) → Physics Initial chart check → Treatment delivery
Treatment Plan Documentation

Standard template

1. Treatment planning note

2. 3-plane screenshot with beam arrangement on the body contour
   – Absolute dose with isodose lines
   – Fields tab shown with all tx fields and their parameters visible
   – 3D view of body contour with treatment fields shown
   – PTVs and major organs displayed

3. BEVs for each treatment field

4. DVHs. 5 Curves maximum per page

5. IF SRS/SBRT – Conformity/constraint spreadsheet

6. Long treatment plan report

7. Short treatment plan report

8. Plan Sum 3-plane screenshot with beam arrangement on the body contour

9. DVHs (Plan Sum). 5 Curves maximum per printout
Treatment Plan Documentation

• Possible issues in Manual Method
  – Incorrect order of documents
  – Missing sections
  – Incorrect sections
  – Rework

• All of the above lead to extra TIME to fix.
<table>
<thead>
<tr>
<th>Treatment Site</th>
<th># of Plans</th>
<th>Plan sum printed</th>
<th>Printing time (min)</th>
<th>Average time/plan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planner 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rectum Boost</td>
<td>1</td>
<td>yes</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Prostate</td>
<td>1</td>
<td>no</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Prostate</td>
<td>1</td>
<td>no</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Whole Brain</td>
<td>1</td>
<td>no</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>pelvis 4 field</td>
<td>1</td>
<td>no</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>RAO/LPO</td>
<td>1</td>
<td>yes</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>chestwall (tangents+supraclav+PAB)</td>
<td>3</td>
<td>yes</td>
<td>55</td>
<td>15 min</td>
</tr>
<tr>
<td><strong>Planner 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rectum boost</td>
<td>1</td>
<td>no</td>
<td>12</td>
<td>12 min</td>
</tr>
<tr>
<td>Head &amp; Neck replan</td>
<td>1</td>
<td>no</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Pelvic nodes</td>
<td>1</td>
<td>no</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>GBM Brain</td>
<td>1</td>
<td>no</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>3 arc pelvis</td>
<td>1</td>
<td>no</td>
<td>10</td>
<td>11 min</td>
</tr>
<tr>
<td>Prostate Boost</td>
<td>1</td>
<td>no</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>pelvis</td>
<td>1</td>
<td>no</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Lt Breast</td>
<td>1</td>
<td>no</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Prostate Boost</td>
<td>1</td>
<td>no</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><strong>Planner 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole Brain</td>
<td>1</td>
<td>no</td>
<td>5</td>
<td>10 min</td>
</tr>
<tr>
<td>Rt Breast</td>
<td>1</td>
<td>no</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Rt Breast</td>
<td>1</td>
<td>no</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Whole Brain</td>
<td>1</td>
<td>no</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Rt Lung 3D</td>
<td>1</td>
<td>no</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>GBM RA</td>
<td>1</td>
<td>no</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>chestwall (tangents+tangents with bolus+supraclav+PAB)</td>
<td>4</td>
<td>yes</td>
<td>36</td>
<td>10 min</td>
</tr>
<tr>
<td>Pelvis 3D</td>
<td>1</td>
<td>no</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Breast Boost</td>
<td>1</td>
<td>no</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Pelvis</td>
<td>1</td>
<td>no</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
## Treatment plans - 2016

<table>
<thead>
<tr>
<th></th>
<th>Temple</th>
<th>Killeen</th>
<th>Waco</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>108</td>
<td>36</td>
<td>49</td>
</tr>
<tr>
<td>Feb</td>
<td>84</td>
<td>42</td>
<td>46</td>
</tr>
<tr>
<td>Mar</td>
<td>71</td>
<td>19</td>
<td>36</td>
</tr>
<tr>
<td>Apr</td>
<td>72</td>
<td>32</td>
<td>39</td>
</tr>
<tr>
<td>May</td>
<td>89</td>
<td>25</td>
<td>36</td>
</tr>
<tr>
<td><strong>Total (2016)</strong></td>
<td><strong>424</strong></td>
<td><strong>154</strong></td>
<td><strong>206</strong></td>
</tr>
</tbody>
</table>

Grand total = 784

\[ \sim 784 \times 12 \text{ min} = 9408 \text{ min of documentation preparation time} \]
Plan printing with Eclipse Script video

Whole Brian printed plan

SBRT Rt Lung printed plan

Rt Lung IMRT
Printing time with Eclipse script

• One click documentation – PDF format
• Typical printing time is ~ 1 min for one plan
• Standard order for all plans
  — Incorrect order
  — Missing sections
  — Incorrect /irrelevant information
Commissioning of Plan Printing Script

• Critical testing was conducted
  – Patient information
  – Prescription
  – Naming conventions
  – Dose constraints verification table
  – Beams eye view: orientation, MLC apertures, annotations, etc.
  – DVH plots
  – MU calculation point data
  – Treatment and set-up field data
  – Couch shifts
  – Calculation algorithms information
  – Tested on multiple plans (diff sites, fractionations, and patients)
Future

• Plan Sums
  – Script for DVH analysis
  – Script for plan sum documentation

• Plan check program
  – Verify contour naming convention
  – Verify contours

• Updating current scripts in tandem with Eclipse TPS upgrades
Conclusions

• Automation works
• Scripting tool
  – very effective
  – Avoids human error
  – TIME
• Morale
  – Dosimetrists, physicists and physicians love the tool
  – Path towards effectiveness of team members
Acknowledgements

• Andrew Morrow
  – Chief of Treatment Planning @ BSW
  – Script developer/programmer

• Dharanipathy Rangaraj
  – Chief of Physics Division @ BSW