MY PhD STORY

MONTE CARLO PORTAL DOSIMETRY

MARY PW CHIN

Velindre Cancer Centre
Canolfan Ganser Felindre
Presentation Overview

PORTAL DOSIMETRY

OTHERS’ vs MINE
• METHOD
• RESULTS

THINGS FOR VARIAN TO SORT OUT

MONTE CARLO
• A WORD OF CAUTION
• THE (NON-)ISSUE OF SPEED

WHAT I HAVEN’T DONE
MANY THINGS CAN GO WRONG.
SOME HORROR STORIES

Adverse Event Report

PHILIPS MEDICAL SYSTEMS Pinnacle3 Treatment Planning System

Event Type: Death  Patient Outcome: Death

Event Description:
A radiation treatment was planned using the Philips Pinnacle3 radiation treatment planning system. The plan called for the use of a motorized wedge on an Elekta SL-18 dual energy accelerator. The target machine for the plan had a motorized wedge and did not support the use of a Pinnacle3 planning machine using a non-motorized wedge. The plan required a motorized wedge. The plan also required two motorized wedges. The treatment machine intended for the treatment did not support two motorized wedges. Pinnacle3 completed the treatment plan and the user exported it to impact sequencer record and verify system. On import, sequencer removes leading and trailing

Check Man, Method & Machine errors

• BEFORE TREATMENT
• DURING TREATMENT
PORTAL DOSIMETRY

GEOMETRIC

• BEFORE TREATMENT
• DURING TREATMENT

hitting right area?
giving right dose?

DOSIMETRIC

PROFILE

$x/\text{cm}$
dose/[Gy]

$10^{-12}$
CHAPTER 1. INTRODUCTION

OTHERS’ METHODS

EXCEPT A FEW ...

Table 1.2: Clinical applications of EPIDs.

<table>
<thead>
<tr>
<th>Application</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient setup verification</td>
<td>Lam et al. [1993], Elgayed et al. [1993], Hunt et al. [1995], Bel et al. [1995], Luchka and Shalev [1996], Pouliot and Lirette [1996], Millar et al. [1997], Yan et al. [1998], Girouard et al. [1998], Bozwala et al. [1999], Samson et al. [1999], Pisani et al. [2000], de Boer et al. [2001], Hatherly et al. [2001], Phillips et al. [2002], Vetterli et al. [2004]</td>
</tr>
<tr>
<td>MLC trajectory verification</td>
<td>Keller et al. [1998], Partridge et al. [2000], James et al. [2006], Chen et al. [2002], Ploeger et al. [2002], Popescu et al. [2002], Samant et al. [2002], Vieira et al. [2002], Fielding et al. [2002], Obcemea et al. [2003], Sonke et al. [2004], Chang et al. [2004]</td>
</tr>
<tr>
<td>Linac QA</td>
<td>Kirby and Williams [1995], Luchka et al. [1996], Hierholz et al. [1999]</td>
</tr>
<tr>
<td>Compensator design and verification</td>
<td>Roback and Gerbi [1995], Evans et al. [1998], Menon and Sloboda [2003]</td>
</tr>
<tr>
<td>Organ motion studies</td>
<td>Vigneault et al. [1997], Kroenwijk et al. [1998], Kubo et al. [1999], Vanttenhoven et al. [1991], Kaatee et al. [2002], Ford et al. [2002], van Asselen et al. [2003], Berbeco et al. [2003]</td>
</tr>
<tr>
<td>2D dose verification</td>
<td>Yin et al. [1994], Zhu et al. [1995], Essers et al. [1996], McNeutt et al. [1996, 1997], Boellaard [1998], Keller et al. [1998], Curtin-Savard and Podgorsak [1999], Psma et al. [1999], El-Mohri et al. [1999], Chang et al. [2001], van Esch et al. [2004], McCurdy et al. [2004], Spezi and Lewis [2002], Grein et al. [2002], Chang et al. [2002], Iyer et al. [2003], Greer and Popescu [2003], Warkentin et al. [2003], van Esch et al. [2004]</td>
</tr>
</tbody>
</table>
MY METHOD

\[ D = \int \int \int \ldots \]

1. **EPID**

2. **CALIBRATE**

**portal dose**

**pixel value**

**PHOTON ELECTRON POSITRON**
The use of an aSi-based EPID for routine absolute dosimetric pre-treatment verification of dynamic IMRT fields

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Abstract

**Background and purpose:** In parallel with the increased use of intensity modulated radiation treatment (IMRT) fields in radiation therapy, flat panel amorphous silicon (aSi) detectors are a common standard in radiation therapy equipment. In order to minimize the workload related to the quality assurance of the IMRT fields, we have explored the possibility of using a commercially available aSi portal imager for absolute dosimetric verification of the delivery of dynamic IMRT fields.

**Patients and methods:** We investigated the use of the characteristics of an aSi portal imager (LIM-100, Varian Medical Systems), using an acquisition mode especially developed for portal dose (PD) integration during delivery of a static or dynamic-radiation field. Secondly, the dose calculation algorithm of a commercially available treatment planning system (Elekta Synergy, Varian Medical Systems) was modified to allow prediction of the PD image, i.e. to compare the intended fluence distribution with the fluence distribution as actually delivered by the dynamic multileaf collimator. Absolute rather than relative dose prediction was applied. The PD image prediction was compared to the corresponding acquisition for several clinical IMRT fields by means of the gamma evaluation method.

**Results and conclusions:** The acquisition mode is accurate in integrating all PD over a wide range of monitor units, provided detector saturation is avoided. Although the dose deposition behaviour in the portal image detector is not equivalent to the dose to water measurements, it is reproducible and self-consistent, lending itself to quality assurance measurements. Gamma evaluations of the predicted versus measured PD distribution were within the pre-defined acceptance criteria for all clinical IMRT fields, i.e. allowing a dose difference of 3% of the local field dose in combination with a distance to agreement of 3 mm.
OTHERS’ RESULTS

- small air gap ✗
- LARGE air gap ✓

with a 5 cm air gap correspond very well (with an uncertainty of about 1%, 1 s.d.) with the exit dose OARs obtained with the ionization chamber. Note that the OAR provides only information about the dose at off-axis locations relative to the dose on the central axis. Images obtained with a 5 cm air gap will be used to predict exit dose OARs with a better spatial resolution than the ionization chamber exit dose measurements. The OARs obtained from transmission dose profiles measured with the EPID with a 50 cm air gap overestimate, however, the dose behind the air inhomogeneity by about 11%. Intermediate results have been obtained for other air gaps. The results in Fig. 3 demonstrate that transmission doses at large air gaps can not be used to represent exit dose distributions.

Fig. 3. Nonconverted transmission dose profiles, measured with the EPID with a 5 cm (solid line) and 50 cm air gap (dashed line) behind the inhomogeneous phantom. Exit dose measurements performed with an air-filled ionization chamber are indicated with dots. The transmission dose profiles are normalized to the absolute dose values behind the polystyrene insert of the inhomogeneous phantom.
**MY RESULTS**

**FIELD SIZE**
- OTHER METHODS
- FIELD SIZE DEPENDENT
- OTHER METHOD
- NO PHANTOM/PATIENT

**GANTRY ANGLE**
- OTHER METHODS
- NO GANTRY ROTATION
- OTHER METHODS
- BUILDUP SLAB ON EPID

**AIR-GAP DISTANCE**
- OTHER METHODS
- BREAKDOWN AT SMALL AIR GAPS

EPID
VARYING FIELD SIZE
VARYING AIR-GAP DISTANCE
- measured, 28 cm gap
- predicted, 28 cm gap

position (cm)
VARYING
GANTRY ANGLES
### EPI D TYPES STUDIED

<table>
<thead>
<tr>
<th>SLIC</th>
<th>a-Si</th>
</tr>
</thead>
</table>

States + Europe ≠

- **Why still study SLIC?**
- **Isn’t it obsolete?**
- **Why amorphous? Why Si but not Ge?**
WHETHER MONTE CARLO OR KERNELS

THINGS FOR VARIAN TO SORT OUT
<table>
<thead>
<tr>
<th>OPEN FIELD</th>
<th>OPEN FIELD AFTER GANTRY ROTATION(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXPECTED</td>
<td>FOUND</td>
</tr>
<tr>
<td>Arm problem: sorted in aS1000?</td>
<td></td>
</tr>
</tbody>
</table>
IMRT DOSE VERIFICATION
existing/reported techniques

integrated image
“IMRT mode”

missing dose
beam on

extra dose ‘ghosting’
every 65th frame
beam off

segment-by-segment verification not possible on PortalVision
can’t retrieve individual frames

change in sensitivity
(a-Si is better)

unclean discharge / double-counting
(SLIC is better)
IMRT DOSE VERIFICATION
existing/reported techniques

integrated image
“IMRT mode”

non-integrated image
“standard mode”

PLANNED MU × Σ (CALCULATED DISTRIBUTION
× PLANNED MU)

CALC DIST
PLAN CALCULATED USING MC / SC

tells nothing more than

CALCULATED DISTRIBUTION

MU LEFT UNCHECKED!
IMRT DOSE VERIFICATION
our proposed alternative

- integrated image
  "IMRT mode"
- non-integrated image
  "standard mode"

- customised sequence templates
PROPOSED ALTERNATIVE

BEAM ON

step-and-shoot field

BEAM OFF

segment #1  segment #2  segment #3  ...  segment #n-1  segment #n

IF $\alpha_n = \beta_n = \text{PLANNED}$

- MU ✓
- LEAF POSITION ✓

IF $\alpha_n \neq \beta_n$ AND ONE OF THE PAIR = PLANNED

- MU ✗
- LEAF POSITION ✓

IF NEITHER $\alpha_n$ NOR $\beta_n$ = PLANNED

- HAYWIRE!

* leaf transition

↑ image
MONTE CARLO

A WORD OF CAUTION

Why stress? Just plug in the numbers, the computer will do everything for you!

Don’t take me as a BLACK BOX.
MONTE CARLO RESULTS

\[ \text{TALLY} \pm \text{UNCERTAINTY \%} \]

- Increase sampling
- More particles
- Re-use particles
- Restart
- Recycle

\( T \) stabilisation

\( U \) monotonic decrease
not stabilising!

\[ T \]

\[ U \]

8,512,980 photons and charged particles

not decreasing!

expected

surprise
POINT WHERE IT'S DARK ENOUGH SHOULD TELL US HOW FAR WE NEED TO RUN THE SIMULATION.

8Gb!
WHEN REPEATED WITHOUT ELECTRONS
*ie setting contaminant electrons exiting linac = 0

PHSP CONTAINS INCORRECT REPRESENTATION OF ELECTRONS.
1. BREMSSTRAHLUNG SPLITTING

- Electron
- Photon
- Photon
- Photon

2. RUSSIAN ROULETTE

- Electron
- Electron
- Electron

 survives!
Large efficiency improvements in BEAMnrc using directional bremsstrahlung splitting

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Ionizing Radiation Standards, National Research Council of Canada, Ottawa K1A OR6, Canada

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The introduction into the BEAMnrc code of a new variance reduction technique, called directional bremsstrahlung splitting (DBS), is described. DBS uses a combination of interaction splitting for bremsstrahlung, annihilation, Compton scattering, pair production and photoabsorption, and Russian Roulette to achieve a much better efficiency of photon beam treatment head simulations compared to the splitting techniques already available in BEAMnrc (selective bremsstrahlung splitting, SBS, and uniform bremsstrahlung splitting, UBS). In a simulated 6 MV photon beam (10 × 10 cm² field) photon fluence efficiency in the beam using DBS is over 8 times higher than with optimized SBS and over 20 times higher than with UBS, with a similar improvement in electron fluence efficiency in the beam. Total dose efficiency in a central-axis depth-dose curve improves by a factor of 6.4 over SBS at all depths in the phantom. The performance of DBS depends on the details of the accelerator being simulated. At higher energies, the relative improvement in efficiency due to DBS decreases somewhat, but is still a factor of 3.5 improvement over SBS for total dose efficiency using DBS in a simulated 18 MV photon beam. Increasing the field size of the simulated 6 MV beam to 40 × 40 cm² (broad beam) causes the relative efficiency improvement of DBS to decrease by a factor of ≈1.7 but is still up to 7 times more efficient than with SBS. © 2004 American Association of Physicists in Medicine. [DOI: 10.1118/1.1788912]
EFFECTS OF TRANSPORT OPTIONS ON PORTAL DOSE PROFILES

Global ECUT = 0
Global PCUT = 0.01
Global SMAX = 0
ESTEPE = 0.25
XIMAX = 0.5
Boundary crossing algorithm = EXACT
Skin depth for BCA = 0
Electron-step algorithm = PRESTA-II
Spin effects = On
Brems angular sampling = KM
Brems cross sections = BH
Bound Compton scattering = On
Pair angular sampling = KM
Photoelectron angular sampling = On
Rayleigh scattering = Off
Atomic relaxations = On

:Stop MC Transport Parameter:

point-to-point difference wrt CAX
### Start MC Transport Parameter:

- Global ECUT = 0
- Global PCUT = 0.01
- Global SMAX = 0
- ESTEPE = 0.25
- XIMAX = 0.5
- Boundary crossing algorithm = EXACT
- Skin depth for BCA = 0
- Electron-step algorithm = PRESTA-II
- Spin effects = On
- Brems angular sampling = KM
- Brems cross sections = BH
- Bound Compton scattering = On
- Pair angular sampling = KM
- Photoelectron angular sampling = On
- Rayleigh scattering = Off
- Atomic relaxations = On

### Stop MC Transport Parameter:

---

**EFFECTS OF TRANSPORT OPTIONS ON PORTAL DOSE PROFILES**

**IN FIELD** | **UMBRA**
MONTE CARLO: SPEED

PROBABILITY THEORY

RADIATION PHYSICS

STATISTICS

NEED $>10^9$ PARTICLES & MONTHS OF RUNTIMES!

www.llnl.gov/peregrine
WAYS OF MAKING IT FAST

VARIANCE REDUCTION
- cut corners during simulation

DENOISING
- smooth data after simulation

CLUSTER & GRID COMPUTING

QUANTUM COMPUTING
- not a reality (yet?)

Quantum computing: Putting it into practice

Jonathan Jones

Will quantum information theory ever lead to practical quantum information technologies? At a conference reviewing the advances of the past two years, delegates looked to the future with cautious optimism.
IDEALLY LIKE POWER GRIDs, GENERATION & SUPPLY SHOULD BE HIDDEN FROM THE USER
LOGIN TO EACH SITE? IF 10 SITES, THEN 10 USERNAMES & 10 PASSWDS!

COMPLETE MESS!

SEND JOBS TO 200 HOSTS @ DIFFERENT SITES: CARDIFF, GLASGOW, ...;

GET 200 × NO. OF OUTPUT FILES OF WHICH SOME WOULD BE BIG-ENDIAN, OTHERS SMALL-ENDIAN.

SOME JOBS WOULD GET STUCK AT LOGIN TO EACH SITE.

SINGLE COMMAND-LINE FROM THE USER. NO FURTHER INTERACTION NEEDED.

eg. 200 PARALLEL RUNS
RESOURCES

1. NGS (UK National Grid Service)
2. Non-dedicated pool of office PCs @ Velindre
3. SGI pool @ Welsh e-Science Centre
4. BEOWULF @ University of Surrey

JOB BROKERS

1. Nimrod/G (by Monash)
2. Condor/G (by Wisconsin)

Globus: project to develop software infrastructure for world-wide distributed computing

ACCESS

1. Local job submission
2. Remote job submission
3. Web portal
UK NATIONAL GRID SERVICE (NGS)

Jobs split into 30 parts

"CLUSTER OF CLUSTERS"

NIMROD not only decides which processor to submit a job, but also which site.

HETEROGENEOUS & MULTI-PLATFORM ENABLED!
WHAT I HAVE DONE

FORWARD PREDICTION

GIVEN THE TREATMENT PLAN, HOW WOULD THE IMAGE LOOK LIKE?

WHAT I HAVEN’T DONE

BACKWARD RECONSTRUCTION

GIVEN THE TREATMENT-TIME IMAGE, WHAT ACTUALLY HAPPENED?
# ACKNOWLEDGMENT

<table>
<thead>
<tr>
<th>PAST</th>
<th>PRESENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhD</td>
<td>Post-doc</td>
</tr>
</tbody>
</table>

[Logo: Cancer Research Wales]

[Logo: EPSRC]
more...
www.marychin.org

c o n t a c t  . . . 
me@marychin.org