HEP software & the GRID
A breakthrough in the fight against cancer

http://www.ge.infn.it/geant4/examples/brachytherapy

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CERN
INFN Genova
National Institute for Cancer Research, IST Genova

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A real-life case

but all the results presented in this talk are general

- Activity initiated at IST Genova, Natl. Inst. for Cancer Research (F. Foppiano et al.)
  - hosted at San Martino Hospital in Genova (the largest hospital in Europe)

- Collaboration with San Paolo Hospital, Savona (G. Ghiso et al.)
  - a small hospital in a small town

Major work by **Susanna Guatelli**


http://www.ge.infn.it/geant4/tesi/
Brachytherapy is a medical therapy used for cancer treatment. Radioactive sources are used to deposit therapeutic doses near tumors, while preserving surrounding healthy tissues.

**Techniques:**
- **endocavitary**
  - lung, vagina, uterus
- **interstitial**
  - prostate
- **superficial**
  - skin

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Radiotherapy treatment planning

- Treatment planning is performed by means of commercial software.
- The software calculates the dose distribution delivered to the patient in a given source configuration.

Open issues

**Precision**
- Commercial systems are based on approximated analytical methods, because of *speed constraints*.
- Approximation in source anisotropy.
- Uniform material: water.

**Cost**
- Each treatment planning software is specific to one technique and one type of source.
- Treatment planning software is expensive (~ hundreds K $/euro).

Monte Carlo simulation is not used in clinical practice (only side studies).

eg. Variseed V 7, Plato BPS, Prowes.
A dosimetric system for brachytherapy

Calculation of 3-D dose distribution in tissue
Determination of isodose curves

Precision
Accurate model of the real set-up
Easy configuration for hospital usage
Speed
Other requirements

Based on Monte Carlo methods
Accurate description of physics interactions
Experimental validation of physics involved

Realistic description of geometry and tissue
Possibility to interface to CT images

Graphic visualisation + User Interface
Elaboration of dose distributions and isodoses

Parallelisation
Access to distributed computing resources

Open to extension and new functionality
Publicly accessible

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Modeling the radioactive source

Plato-BPS treatment planning algorithm makes some crude approximation ($\phi$ dependence, no radial dependence)

**Transverse axis of the source**
Comparison with experimental data

**Longitudinal axis of the source**
Difficult to make direct measurements

Effects of source anisotropy
Rely on simulation for better accuracy than conventional treatment planning software
Validation

Microscopic validation: verification of Geant4 physics
Dosimetric validation: comparison to manufacturer data, protocol data, original experimental data

S. Guatelli et al., Savona Hospital

F. Foppiano et al., IST Genova
Flexibility of modeling

Configuration of
- any brachytherapy technique
- any source type

through an Abstract Factory to define geometry, primary spectrum

CT DICOM interface
- through Geant4 parameterised volumes
- parameterisation function: material

(-preliminary, work in progress)

Phantom
- various materials
  - water, soft tissue, bone, muscle etc.

No commercial general software system!

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2. Running the simulation

In order to run your simulation:
fix the simulation parameters,
the number of events of the run.

Then press BeamOn.
The result of the simulation is the dose distribution in the plane containing the source.

2.1 Choose the simulation parameters

2.2.1 Choose the radioactive source
Available radioactive sources: I-125, Ir-192, Leipzig

2.2.2 Choose the phantom absorber material
Available materials: water, soft tissue, air

2.2.3 Choose the number of gamma delivered by the source

2.2.4 Press beamOn to run the simulation

2.2.5 Back again to the simulation default parameters if you like!

Run modes:
- demo
- parallel on a cluster
- on the GRID (in preparation)

Simple, friendly user interface for hospital usage even by non-specialists

Fully configurable from the web
Dosimetry

Analysis of the energy deposit in the phantom resulting from the simulation

Dose distribution
Isodose curves

AIDA + Anaphe
for analysis

Python
for interactivity

may be any other AIDA-compliant analysis system

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Bebig Isoseed I-125 source

Isodose curves

0.16 mGy = 100%

y = 0 mm

y = 2 mm

y = 5 mm

y = 1 cm

Dosimetry
Interstitial brachytherapy

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Dosimetry
Endocavitary brachytherapy

MicroSelectron-HDR source

Dosimetry
Superficial brachytherapy

Leipzig applicator

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Performance

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endocavitary brachytherapy</td>
<td>61 min</td>
</tr>
<tr>
<td>Superficial brachytherapy</td>
<td>65 min</td>
</tr>
<tr>
<td>Interstitial brachytherapy</td>
<td>67 min</td>
</tr>
</tbody>
</table>

on an “average” PIII machine, as an “average” hospital may own

Monte Carlo simulation is not practically conceivable for clinical application, even if more precise
Access to distributed computing

Previous studies for parallelisation of a Geant4 based medical application
- speed OK
- but expensive hardware investment + maintenance

Alternative strategy

DIANE

Transparent access to a distributed computing environment

Parallelisation Access to the GRID

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hide complex details of underlying technology

DIANE Distributed Analysis Environment

Parallel cluster processing
- make fine tuning and customisation easy
- transparently using GRID technology
- application independent

See talk by J. Moscicki, Session 1
“DIANE: distributed analysis environment”

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Migration to distributed environment

- The application developer (e.g. Geant4 simulation + analysis) is shielded from complexity of underlying technology

- Not affecting the original code of application
  - standalone and distributed cases is the same code

- Good separation of the subsystems
  - application does not need to know that it runs in distributed environment...
  - the distributed framework (DIANE) does not need to care about what actions application performs internally
Performance: parallel mode

Endocavitary brachytherapy

- 1M events
- 4 minutes 34’’

Superficial brachytherapy

- 1M events
- 4 minutes 25’’

Interstitial brachytherapy

- 5M events
- 4 minutes 36’’

on up to 50 workers, LSF at CERN, PIII machine, 500-1000 MHz

Performance is adequate for clinical application, but...

it is not realistic to expect any hospital to own and maintain a PC farm

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Running on the GRID

- Via DIANE
- Same application code as running on a sequential machine or on a dedicated cluster
  - completely transparent to the user
- Consequence
  - a hospital is not required to own and maintain extensive computing resources to exploit the scientific advantages of Monte Carlo simulation for radiotherapy
  - any hospital – even small ones, or in less wealthy countries, that cannot afford expensive commercial software systems – may have access to advanced software technologies and tools for radiotherapy
- Work in progress: submission to the GRID and retrieval of results from a web portal
  - to facilitate the usage by end-users

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Outlook: other radiotherapeutic techniques

Radiotherapy with extracted beams

M.C. Lopes, L. Peralta, P. Rodrigues, A. Trindade
IPOFG-CROC Coimbra Oncological Regional Center, LIP - Lisbon

In some tumour sites (ex: larynx T2/T3-stage) a 5% underdosage will decrease local tumour control probability from ~75% to ~50%
Conclusions

- A precise dosimetric system, based on Monte Carlo simulation
  - Geant4
- Full dosimetric analysis
  - AIDA + Anaphe
- Simple interface
  - configuration from www
- Fast performance
  - DIANE
- Access to distributed computing resources
  - GRID

- The dream of medical physics for the past 40 years…
Post-conclusion

Medical physics does not only require fast simulation and fancy analysis…

Advanced *functionality* in geometry, physics, visualisation etc.

- **Specific facilities** controlled by a friendly UI
- **Extensibility** to accommodate new user requirements
- **Transparency** of physics
- **User support** from experts
- **Adoption of standards** wherever available
- **Quality Assurance** based on sound software engineering
- **Independent validation** by a large user community worldwide
- **Use of evaluated data libraries**

What in HEP software is relevant to the bio-medical community?
Thanks!

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