A Basic Monte Carlo Course
(Electron Gamma Shower)

Speaker: Dr. Joel Y.C Cheung
Date: 5th Mar 2016, 10:00-13:00
Venue: Room Y302, PolyU, HK

Monte Carlo –
A Statistical Calculation, problem solving

Probability of drawing 6?

1) Perform an actual experiment!
2) Using the Monte Carlo technique!

Monte Carlo - π Calculation

Calculation of π using the Monte Carlo method

\[ x^2 + y^2 = 1 \]

\[ \pi = \text{Area of the square} \times \frac{\text{no. of } \bullet}{\text{no. of } \circ} \]

\[ = 4 \times \frac{11}{19} = 2.32 \]

Calculation of π using the Monte Carlo method – cont.

\[ \pi = \text{Area of the square} \times \frac{\text{no. of } \bullet}{\text{no. of } \circ} \]

\[ = 4 \times \frac{150}{200} = 3.0 \]
Monte Carlo –
Sales Forecast

Monte Carlo in Radiation Physics

Monte Carlo in Radiation Physics

Determine by Random Numbers?

Before Interaction
Position ? (X,Y,Z)
Moving Direction ? (U,V,W)
Energy ? (E)

After Interaction / Next Step
Position ? (X,Y,Z)
Moving Direction ? (U,V,W)
Energy ? (E)
Energy Deposition (EDEP)

Photon or Charge Particle

Sales Forecast Monte Carlo Simulation

Monte Carlo in Radiation Physics

- Monte Carlo modeling of particle transport problems in medical and radiation physics gives more advantages than other techniques.
- Experiments can be done without setting up the physical situation, and results of some “impossible” experiments can be obtained.
- e.g. scoring the numbers of created particles or calculating the relative OPFs of narrow beams.

Radiation Interactions

GNU Free Documentation & public domain
Disadvantage of Monte Carlo Technique

History Runs ~ 1000000

Application: Radiation Protection

Concrete Wall

I-131

Scoring Region

Application: Linear Accelerator Simulation

Primary Collimator
Flattening Filter
Ion Chamber
Upper Jaw
Lower Jaw

Application: Linear Accelerator Simulation (PDD)

Application: Radiosurgery

Gamma Knife
Co-60
Gamma beam
Patient
Target

Application: Radiosurgery (Gamma Knife)
Application: Radiosurgery (X-Knife)

Dose enhancement close to platinum implants for the 4, 6, and 10 MV stereotactic radiosurgery

Application: CT Simulation

"Do Loop" for rotation

Application: CT Simulation

CT x-ray source

Application: DRR Simulation

x-ray source

Application: DRR Simulation

x-ray source

http://www.doseinfo-radar.com/RADARphan.html

Organ Dose !

Image !

Scoring Voxel
The availability of standardized Monte Carlo packages such as:

- EGS4: EGSNRC / EGS5
- BEAM
- ETRANITS
- PENELLOPE
- MCNP
- GEANT

along with the development of more powerful and inexpensive computers has allowed more widespread use of the technique.
EGS4 (Electron Gamma Shower) code

Stanford Linear Accelerator Center - by Nelson, Harayama and Rogers.

http://rcwww.kek.jp/research/egs/

http://rcwww.kek.jp/research/egs/egs5.html

http://rcwww.kek.jp/research/egs/epub.html

EGSnrc Code

http://irs.inms.nrc.ca/
Pseudorandom Number Generators

<table>
<thead>
<tr>
<th>Generator</th>
<th>Randomness</th>
<th>Purity</th>
<th>Approx.</th>
<th>Period or Cycle</th>
<th>Needed to</th>
<th>Output Repetitives</th>
<th>Output Repetitives</th>
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</thead>
<tbody>
<tr>
<td>traditional</td>
<td>available</td>
<td>poor</td>
<td>3^13</td>
<td>100</td>
<td>recommended</td>
<td>3^13</td>
<td>100</td>
</tr>
<tr>
<td>RANDU &amp;</td>
<td>acceptable</td>
<td>poor</td>
<td>3^13</td>
<td>100</td>
<td>recommended</td>
<td>3^13</td>
<td>100</td>
</tr>
<tr>
<td>RANDU &amp;</td>
<td>good</td>
<td>good</td>
<td>3^13</td>
<td>100</td>
<td>recommended</td>
<td>3^13</td>
<td>100</td>
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<tr>
<td>SCARRY &amp;</td>
<td>good</td>
<td>good</td>
<td>3^13</td>
<td>100</td>
<td>recommended</td>
<td>3^13</td>
<td>100</td>
</tr>
</tbody>
</table>

EGS4 Code

EGS4 Structure

EGS4 Distribution / Fortran Compiler

EGS4 folders on PC

EGS4 - Main Folder
Mortran or Fortran

User Code: Tutor1.mor

User Code: CALL SHOWER

DO J=1,1000000 [
   CALL SHOWER 
   (IQIN,EIN,XIN,YIN,ZIN,UIN,VIN,WIN,IRIN,WTIN) 
]

User Code: HOWFAR

SUBROUTINE HOWFAR; 
COMIN/EPCONT,PLADTA,STACK/;

IRL=IR(NP); "SET LOCAL VARIABLE"
IF(IRL.NE.2) [IDISC=1; "TERMINATE THIS HISTORY"] ELSE [ 
$PLAN2P(IRL,IRL+1,1,IRL-1,IRL-1,-1); ]

RETURN;
END;" END OF SUBROUTINE HOWFAR

User Code: AUSGAB

SUBROUTINE AUSGAB(IARG); 
COMIN/EPCONT,SCORE,STACK,GEOM/;

IF (IARG.LE.3) [ 
ESCORE(ITEMP1)=ESCORE(ITEMP1)+EDEP; ]
RETURN;END;"END OF AUSGAB"
Folder Content

HOWFAR (Tutor1)

User Code: Tutor1.mor

Open a DOS prompt

Setup Environment

Mortran to Fortran and Compile
Execute Tutor1

Results of Tutor1

Assignment #1: Al attenuation coefficient

\[ \ln \left( \frac{I_0}{I} \right) = \mu t \]

Assignment #1: Energy Cut Off

- UP / UE (at PEGS)
- PCUT / ECUT (at User Code)
- AP / AE (at PEGS)

Assignment #1: al.inp

Assignment #1: aluminum data file
Assignment #1: al.dat

PEGS4 - Template

Mixture / Compound

Steel

Assignment #1: Result

\[ \ln \left( \frac{I_0}{I} \right) = \mu t \]

- \( I_0 = 1000000 \)
- \( I = 438007 \)
- \( t = 5 \text{cm} \)
- \( \mu = 0.165104 \text{ cm}^{-1} \) (ref 0.165942 cm\(^{-1}\))

Broad Beam \( \mu = ? \)

Assignment #2: Al Bremsstrahlung Spectrum
Assignment #2: Results

Assignment #3: Linac PDD Calculation

Assignment #3: EDEP

- The Meaning of the Main Variables used in EDEP
- Table of a particle's initial coordinates
- Initial weight of a particle
- Linear energy transfer (L.E.T)
- Linear energy transfer (L.E.T) in b/c
- Number of secondary particles generated
- Number of particles from the current
- Number of particles from the current
- Number of particles from the current
- Number of particles from the current

Assignment #3: IARG

<table>
<thead>
<tr>
<th>Table 1(a) Value for IARG and corresponding situation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>IARG</td>
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<tr>
<td>------</td>
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<td>0</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
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</table>

Assignment #3: Results

Thank You!