NE 255
Numerical Simulations in Radiation Transport
Probability and Statics

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Major Components of MC Algorithm

- **PDFs**: the physical/mathematical system must be described by a set of pdfs.
- **Random number generator**: a source of random #s uniformly distributed on the unit interval.
- **Sampling rule**: prescription for sampling the pdf (given having random #s)
- **Scoring**: the outcomes must be accumulated/<u>tallied</u> for quantities of interest
- ***Error estimation**: an estimate of the statistical error (<u>variance</u>) of the solution*
- **Variance Reduction**: methods for reducing the variance and computation time simultaneously
- **Parallelization**: efficient use of computers

Outline / Learning Objectives

1. Probability Density Functions
2. Standard Statistical Quantities
3. Accuracy vs. Precision
4. Central Limit Theorem
5. Relative Error

1. Understand the derivation of basic statistical quantities
2. Be able to explain the difference between accuracy and precision
3. Understand how to interpret and apply confidence intervals
4. Understand derivation and use of relative error

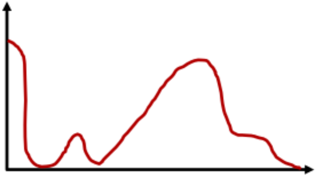
Notes derived from Jasmina Vujic and Paul Wilson

Fundamental Concept

- Many individual particle histories are simulated
- Each physical event is determined by randomly sampling a probability distribution
- Each history can contribute to the physical measurement of interest
  - x_i = contribution of history i
  - Different ways to calculate score
    - Does particle cross surface?
    - How much time does particle spend in particular region?

Fundamental Concept

- Set of individual contributions, x_i, forms a *probability distribution*



- We are interested in the mean value of that contribution, $\overline{x_i}$, and its variance, $S^2_{\overline{x}}$

Two Encounters with Probability Distributions

- Probability distributions for the outcome of each physical event
- We use **Random Sampling** techniques to evaluate these at each occurrence
- Underlying probability distribution for each physical measurement of interest
- We estimate the statistical moments of these distributions to get our physical answers

To the Board

Two Types of MC Methodology

Analog

- Natural laws are **preserved**
- The game is the "analog" of the physical problem of interest (the history of each particle is simulated exactly)

Non-Analog

- To reduce computation time, the strict analog simulation of particles is abandoned (i.e. we CHEAT)
- Variance Reduction techniques:
  - Absorption suppression
  - Russian Roulette (history termination)
  - Splitting (history propagation)
  - Forced collisions
  - Source biasing
  - Hybrid methods

Analog vs. Weighted MC

Analog

- No alteration of PDFs
- At collision, particle is killed if absorbed
- Particle is born with weight 1
- weight unchanged throughout history
- Score when tallying events is 1

Non-Analog (weighted)

- Alter PDFs to favor events of interest
- Particle can have different birth weight
- Weight is altered if biased PDF is used
- Particle survives “absorption” and weight is changed
- Splitting and Rouletting can change weight
- Score current weight when tallying

Probability & Statistics Summary

- Rich variety of statistical analysis is possible.
- The difference between accuracy and precision is important
- Accuracy is not always known and can be difficult to improve
- Precision can be improved by more histories in a measurement, but not always more histories in a problem

Check in about Projects and Presentations

- Reminder: here is the project description https://github.com/rachelslaybaugh/NE255/blob/gh-pages/project/project.pdf
- Here is the project rubric https://github.com/rachelslaybaugh/NE255/blob/gh-pages/project/project_rubric.pdf

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