Monte Carlo Methods - Introduction

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Warm up!!!

- Important Discoveries
- What is it?
- Why do we need it in Data Science?

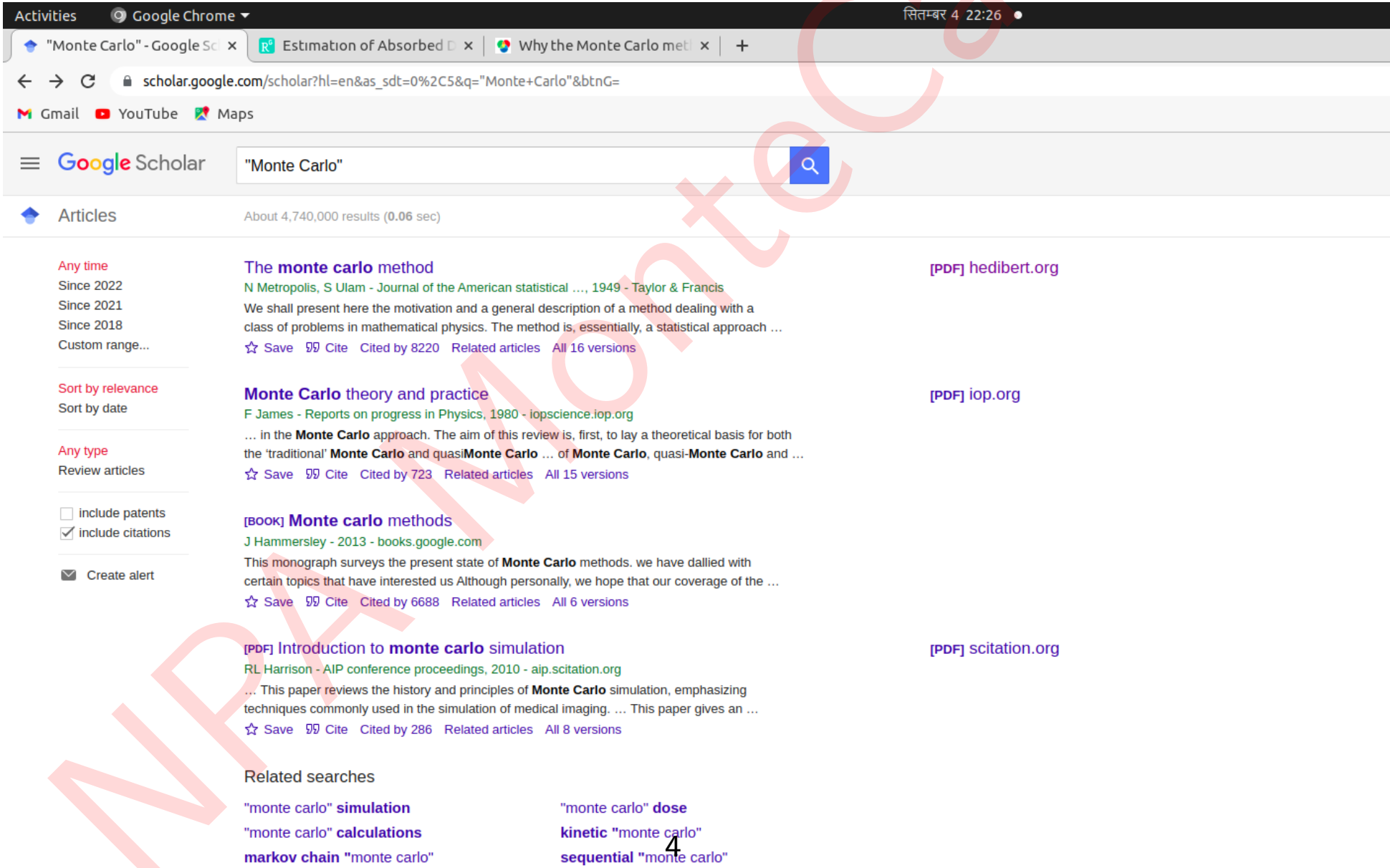
Warm up - what is really it?!!!

You may face multidimensional integration. It comes in Mathematics as well as in Physics, Statistics ....

$$\int \int ..... \int f(x_1)f(x_2).....f(x_n)dx_1dx_2.....dx_n \tag{1}$$

In above equation n may be huge ... 100, 10^4, or 10^6,....?
How to handle such a complex problem? Just think about it....
Does our ways of doing till now work?

Warm up - what is really it?!!!



Warm up - Health

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Physica A: Statistical Mechanics and its Applications

Volume 574, 15 July 2021, 126014

A random walk Monte Carlo simulation study of COVID-19-like infection spread

S. Triambak [a], D.P. Mahapatra [b]

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Abstract

Recent analysis of early COVID-19 data from China showed that the number of confirmed cases followed a subexponential power-law

Warm up - Health

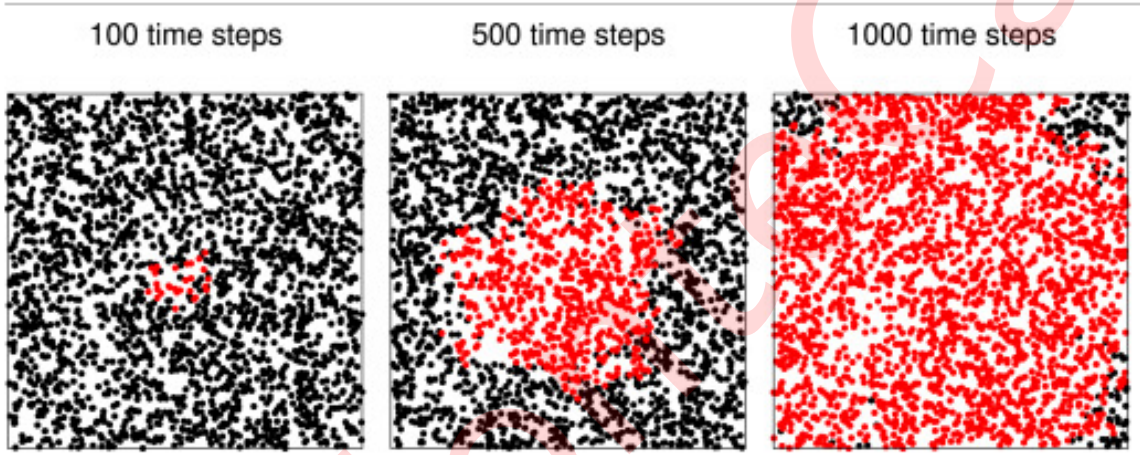

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Fig. 1. An example of proximity-based infection spread obtained using the random walk Monte Carlo simulations described in this work. Each of the panels shown above has a population of 2.5k over a unit area. The average distance $\langle r \rangle$ between any two points is $= 0.02$ units. In this case every point (walker) takes randomly directed steps of length $l = 0.25 \langle r \rangle$. Further details are described in the text below.

Warm up - Health

Austin Journal of Radiology

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Austin Publishing Group

Special Article - Therapeutic Radiology

Estimation of Absorbed Dose Distribution in Different Organs during the CT Scan: Monte Carlo Study

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Abstract

This work aimed to validate the accuracy of a Monte Carlo source model of the Ge Lightspeed CT scanner using organ doses measured in specific human adult phantoms. The x-ray output of the Ge Lightspeed multidetector CT scanner was simulated within the Monte Carlo code. The resulting source model was able to perform various real simulated scan model helical Computed Tomography (CT) scans of varying scan parameters such as kVp, mAs, filtration, pitch, and beam collimation. This work has been performed by using real Computed Tomography (CT) protocols to patients in public hospitals in Turkey. We used Monte Carlo simulation methods with real height and weight of patients and Computed Tomography (CT) scanners real parameters. Absorbed organ doses have been calculated by using Monte Carlo simulation. The results showed that changes in mAs value are significantly important for obtaining the risk of cancer from dose rates. Additionally, the dose received by each organ has been calculated and the results showed that Monte Carlo is a strong and effective tool in radiological investigations.

Keywords: CT scan; Absorbed dose; Monte carlo simulation

Introduction

Diagnostic radiology is a significant tool for clinical diagnosis and includes general x rays, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), ultrasound, mammography, etc. Diagnostic radiology is part of medicine that uses medical imaging facility and technology to diagnose disease and helps define the structures inside in human body. Diagnostic radiology uses the imaging technologies of X-rays radiography, computed tomography, magnetic resonance imaging, ultrasound, mammography, etc. Common classifications of CT scans are abdominal, bone, head and vascular system. CT scanning is the one of most used units in diagnostic radiology and these units combine the use of X-rays and computer processing to generate tomographic images of the body. The use of CT in radiology and medical imaging has been growing in the world. CT is useful as it allows the radiologist, to view a cross-sectional picture of the entire body. CT is painless, fast, and accurate and CT scan uses x-ray equipment and computers to produce medical images that often can make more detailed image than conventional radiography. CT scans use ionizing radiation as used in other x-rays units. In clinical, the benefits of a correct diagnosis preponderance most accurate, reliable, and versatile in accomplishing this task [1-8].

In the Monte Carlo method, the patient and CT scanner are simulated using a computational anatomic model of the patient and an x-ray source model representing the scanner's beam output. However, to ensure the accuracy of these calculations, these CT source models must be benchmarked and validated against actual experimental measurements made on the scanners they simulate. In the past, most validation studies were accomplished using standard CT Dose Index (CTDI) phantoms, but in recent years, anthropomorphic phantoms have been increasingly utilized [9,10]. Mathematical phantoms or MIRD phantoms have been produced [11] which were the first models of human phantoms to be widely used in dosimetry studies involving X-ray exposure by the Monte Carlo method.

However, the organs in these phantoms are described by mathematical equations with limited representation of the actual structure of a human body and its chemical and physical characteristics [12]. Voxel-based phantoms created from tomography images present a geometry which adequately represents a patient, including internal organ, displacements, and deformations. These phantoms are recommended for dosimetric studies with the Monte

Warm up - Health

- Case of Siamese Twins
- Pharmacy
- MC dose calculation in the radiotherapy treatment

Warm up - Artificial intelligence

Outline

Highlights
Abstract
Keywords
1. Introduction
2. Adapting MCTS
3. Examples of usage
4. Quality of decisions
5. Conclusion & future work
Author statement

References

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Computers in Industry
Volume 128, June 2021, 103433

Monte Carlo Tree Search for online decision making in smart industrial production

Richard Senington, Bernard Schmidt, Anna Syberfeldt

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Monte Carlo methods are also pervasive in artificial intelligence and machine learning. Many important technologies used to accomplish machine learning goals are based on drawing samples from some probability distribution and using these samples to form a Monte Carlo estimate of some desired quantity.

Warm up - Risk Analysis

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Reliability Engineering & System Safety

Volume 199, July 2020, 106792

Risk analysis of an underground gas storage facility using a physics-based system performance model and Monte Carlo simulation

Zaki Syed, Yuri Lawryshyn

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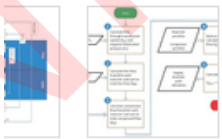
Highlights

- A risk analysis model of underground gas storage facility operational reliability.
- Physics-based performance model combined with Monte Carlo simulation of disruptions.



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Warm up - Sensitivity

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European Journal of Operational Research

Volume 298, Issue 1, 1 April 2022, Pages 229-242

Stochastics and Statistics

Sensitivity estimation of conditional value at risk using randomized quasi-Monte Carlo

Zhijian He

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https://doi.org/10.1016/j.ejor.2021.11.013 Get rights and content

Abstract

Conditional value at risk (CVaR) is a popular measure for quantifying portfolio risk. Sensitivity analysis of CVaR is common in risk management and gradient-based optimization algorithms. In this paper, we study the infinitesimal perturbation analysis estimator for CVaR sensitivity using randomized quasi-Monte Carlo (RQMC) simulation.

Warm up - powerplant

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ISA Transactions
Volume 100, May 2020, Pages 171-184

Research article

Nonlinear robust fault diagnosis of power plant gas turbine using Monte Carlo-based adaptive threshold approach

Saeed Amirkhani [a, b], Ali Chaibakhsh [a, b] ✉, Ali Ghaffari [c]

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https://doi.org/10.1016/j.isatra.2019.11.035

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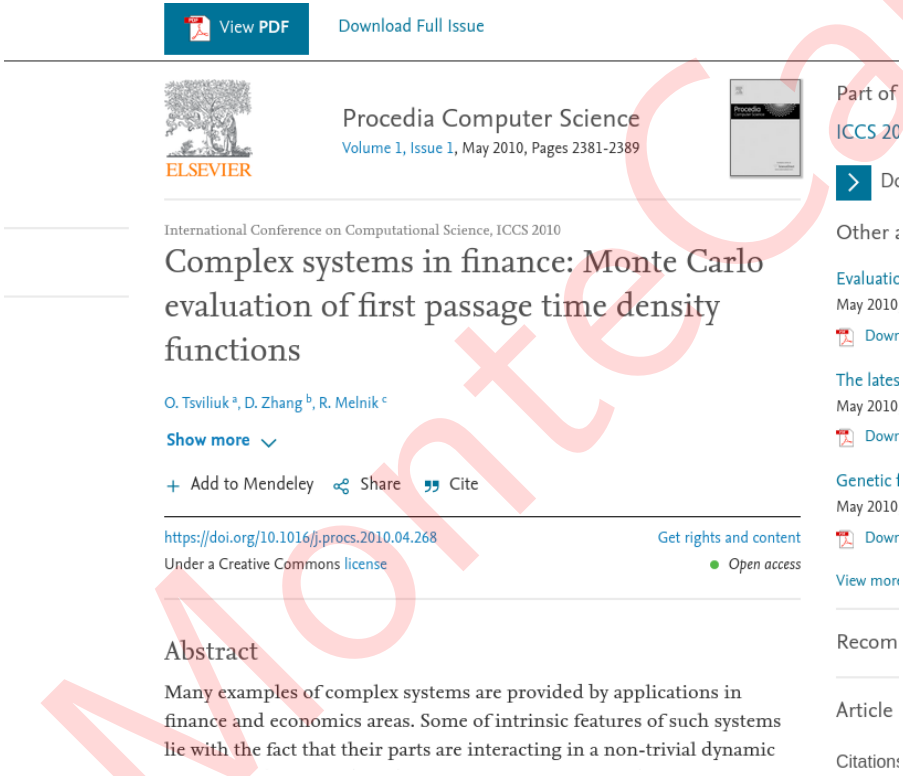
Highlights

- The adaptive threshold approach is used for the gas turbine fault diagnosis.
- Adaptive threshold bounds are determined based on Monte Carlo simulations.
- The robustness of fault detection is analysed through

Warm up - Finance



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Procedia Computer Science
Volume 1, Issue 1, May 2010, Pages 2381-2389

Part of ICCS 20

International Conference on Computational Science, ICCS 2010

Complex systems in finance: Monte Carlo evaluation of first passage time density functions

O. Tsviliuk [a], D. Zhang [b], R. Melnik [c]

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Abstract

Many examples of complex systems are provided by applications in finance and economics areas. Some of intrinsic features of such systems lie with the fact that their parts are interacting in a non-trivial dynamic

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Monte Carlo analysis is useful in risk analysis because many investment and business decisions are made on the basis of one outcome. In other words, many analysts derive one possible scenario and then compare that outcome to the various impediments to that outcome to decide whether to proceed.

Warm up - Physics

- diffusion Limited Aggregation

Warm up - what is really it?!!!

- Monte Carlo methods, or Monte Carlo experiments, are a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results. The underlying concept is to use randomness to solve problems that might be deterministic in principle.
- In a Monte Carlo simulation (method) we attempt to follow the 'time dependence' of a model for which change, or growth, does not proceed in some rigorously predefined fashion (e.g. according to Newton's equation of motion) but rather in a stochastic manner which depends on a sequence of random numbers which is generated during the simulation

Warm up - what is really it?!!!

- Monte Carlo method is used to estimate the possible outcomes of an uncertain event. The Monte Carlo Method was invented by John von Neumann and Stanislaw Ulam during World War II to improve decision making under uncertain conditions. It was named after a well-known casino town, called "Monte Carlo" in Monaco, since the element of chance is core to the modeling approach, similar to a game of roulette.

- Monte Carlo Simulations have assessed the impact of risk in many real-life scenarios, such as in artificial intelligence, stock prices, sales forecasting, project management, and pricing.

Warm up - What is it?!!!

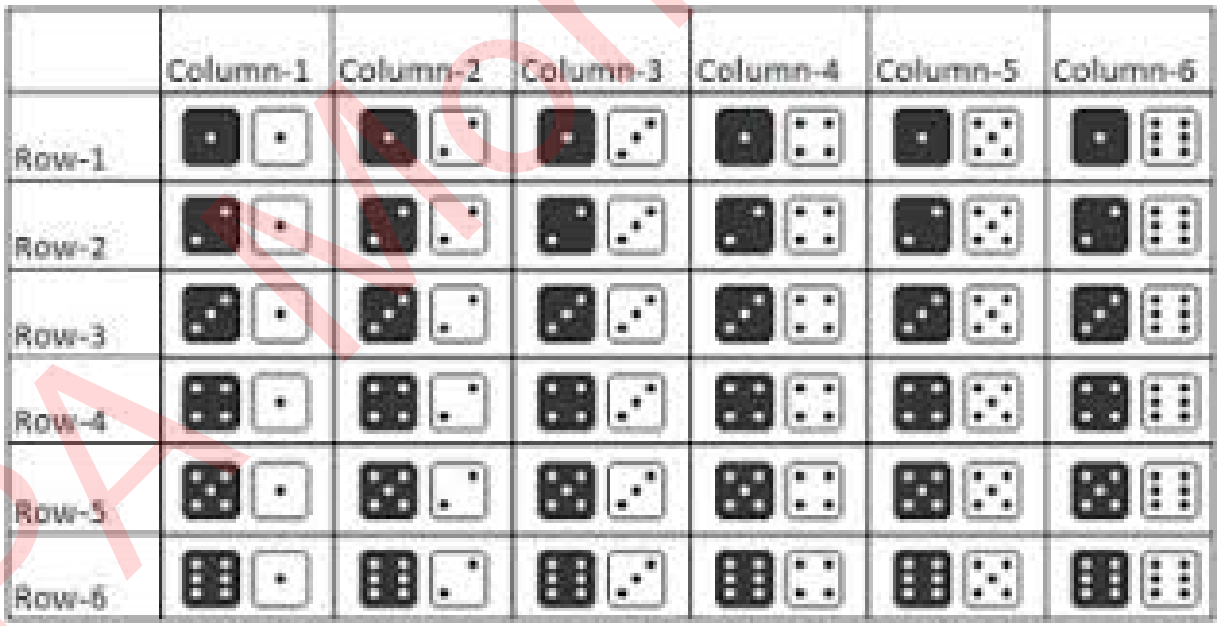
- When Ulam was in hospital he was playing cards (just for time passing) and got the idea of random sampling. He then applied this idea along with Neuman to solve the problem of "neutron diffusion" in the Manhattan project
- Monte Carlo algorithms are simple, flexible, and scalable. When applied to physical systems, Monte Carlo techniques can reduce complex models to a set of basic events and interactions, opening the possibility to encode model behavior through a set of rules which can be efficiently implemented on a computer.
- However he published paper about MC simulation only in 1949 from LANL (Los Alamos National Lab)

Warm up - What is it?!!!

- Take a random sample of given population. Calculate many different outcomes and their probabilities of occurrence
- This outcome represents the desired results.

Warm up - What is it?!!!

- Consider a simple example of rolling dice. Assume that you want to determine the probability of rolling a seven using two dice with values one through six. There are 36 possible combinations for the two dice, six of which will total seven, as shown in the following image.



Warm up - What is it?!!!

- This means that mathematical probability of rolling a seven is six in 36, or 16.67 percent.
- But is the mathematical probability the same as the actual probability? Or are there other factors that might affect the mathematical probability, such as the design of the dice themselves, the surface on which they are thrown, and the technique that is used to roll them?
- To determine the actual probability of rolling a seven, you might physically roll the dice 100 times and record the outcome each time. Assume that you did this and rolled a seven 17 out of 100 times, or 17 percent of the time. Although this result would represent an actual, physical result, it would still represent an approximate result. If you continued to roll the dice again and again, the result would become less and less approximate.

Warm up - What is it?!!!

- A Monte Carlo simulation is the mathematical representation of this process. It allows you to simulate the act of physically rolling the dice and lets you specify how many times to roll them. Each roll of the dice represents a single iteration in the overall simulation; as you increase the number of iterations, the simulation results become more and more accurate. For each iteration, variable inputs are generated at random to simulate conditions such as dice design, rolling surface, and throwing technique. The results of the simulation would provide a statistical representation of the physical experiment described above.

Warm up - What is it?!!!

- Bayesian Statistics is fundamentally all about modifying conditional probabilities – it uses prior distributions for unknown quantities which it then updates to posterior distributions using the laws of probability. In fact Bayesian statistics is all about probability calculations!
- MC method is some how based on the Bayesian Statistics
- Bayesian Statistics is a theory in the field of statistics based on the Bayesian interpretation of probability where probability expresses a degree of belief in an event