

## 14.1: Monte Carlo Simulation

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The concept of Monte Carlo simulation was devised by the mathematicians Stan Ulam and Nicholas Metropolis, who were working to develop an atomic weapon for the US as part of the Manhattan Project. They needed to compute the average distance that a neutron would travel in a substance before it collided with an atomic nucleus, but they could not compute this using standard mathematics. Ulam realized that these computations could be simulated using random numbers, just like a casino game. In a casino game such as a roulette wheel, numbers are generated at random; to estimate the probability of a specific outcome, you could play the game hundreds of times. Ulam's uncle had gambled at the Monte Carlo casino in Monaco, which is apparently where the name came from for this new technique.

There are four steps to performing a Monte Carlo simulation:

1. Define a domain of possible values
2. Generate random numbers within that domain from a probability distribution
3. Perform a computation using the random numbers
4. Combine the results across many repetitions

As an example, let's say that I want to figure out how much time to allow for an in-class quiz. Say that we know that the distribution of quiz completion times is normal, with mean of 5 minutes and standard deviation of 1 minute. Given this, how long does the test period need to be so that we expect all students to finish the exam 99% of the time? There are two ways to solve this problem. The first is to calculate the answer using a mathematical theory known as the statistics of extreme values. However, this involves complicated mathematics. Alternatively, we could use Monte Carlo simulation. To do this, we need to generate random samples from a normal distribution.

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