

What Is a Monte Carlo Simulation?

CHEAT SHEET

The most powerful computational method of the 20th century is built on a single counterintuitive truth: you can find a precise answer to an unsolvable problem by deliberately choosing to be approximate.

CAST

Stanisław Ulam

Polish-American mathematician who invented Monte Carlo

John von Neumann

Hungarian-American mathematician who formalized the method

Nicholas Metropolis

American physicist and co-developer who coined the name

Los Alamos Laboratory

Postwar weapons lab where method was developed

Casino de Monte-Carlo

Monaco casino that gave the method its name

Monte Carlo Simulation

Estimation by random sampling and averaging

Law of Large Numbers

Mathematical guarantee that powers Monte Carlo

Gambler's Fallacy

Common misreading of probability that inverts the law

THE STORY

1

Ulam plays solitaire while recovering from brain surgery

In 1946 at Los Alamos, Ulam convalesced after emergency brain surgery by playing solitaire, and began wondering about the true probability of winning a hand of Canfield. The combinatorics of a 52-card deck were too vast for any analytic solution to exist.

2

Sampling replaces calculation as the core insight

Ulam realized that instead of deriving the probability mathematically, he could just play a hundred games and count wins. The Law of Large Numbers guarantees that averaging enough trials reveals the true underlying probability — estimation by experience rather than derivation.

3

Von Neumann and Metropolis formalize the bedside idea

Ulam brought the concept to von Neumann, who grasped its potential immediately and helped convert intuition into a

rigorous computational framework. Metropolis joined as co-developer, and the three built a method Los Alamos could deploy on early electronic computers.

4

Neutron diffusion becomes Monte Carlo's first real target

The first application was modeling neutron paths through fissile material for nuclear weapons research — a problem with too many cascading variables for direct analysis. Simulating thousands of individual neutron paths and averaging results produced actionable answers that pure math could not.

5

Four universal steps underpin every Monte Carlo method

Every Monte Carlo application follows the same sequence: define a domain of inputs, sample randomly from a probability distribution over that domain, run a deterministic computation on each sample, then aggregate by averaging. The key asymmetry is that each individual trial is trivially easy even when the global problem is analytically intractable.

6

Proportions converge; absolute gaps widen — know the difference

The Law of Large Numbers governs proportions and averages, not raw counts. After a million coin flips, the proportion of heads nears 0.5, but the absolute gap between heads and tails almost surely grows. Believing probability 'corrects itself' is the gambler's fallacy — the coin has no memory and owes you nothing.

CONNECTIONS



REMEMBER

- ◆ Ulam conceived Monte Carlo in **1946** while recovering from emergency brain surgery in Los Alamos.
- ◆ A standard **52-card deck** has so many possible arrangements that enumerating every solitary outcome was computationally impossible in 1946.
- ◆ The **Law of Large Numbers** states that the average of many independent random trials converges to the true mean of the underlying distribution.
- ◆ After **one million** coin flips converging to roughly 50% heads, the absolute gap between heads and tails almost surely grows larger, not smaller.
- ◆ The **Casino de Monte-Carlo** in Monaco, frequented by Ulam's uncle, gave the simulation method its enduring name.
- ◆ Every Monte Carlo method follows exactly **four steps**: define a domain, sample randomly, run a deterministic computation, then aggregate by averaging.
- ◆ The first real Monte Carlo application modeled **neutron diffusion** paths through fissile material for nuclear weapons research — not card games.
- ◆ The **gambler's fallacy** is the false belief that probability corrects itself — that a streak of tails makes heads more likely on the next flip.