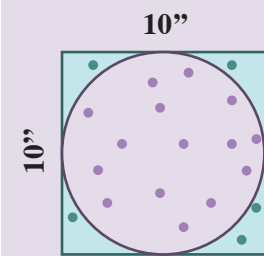


# The Statistics Guiding us from History into the Future

Statistical methods can be used to estimate the probability of events and different conditions within a system (a part of the universe which we have chosen to study the changes of). When it comes to complex systems with many variables, we need methods that can operate with input from many different elements.

## Markov Chain Monte Carlo

Markov Chain Monte Carlo (MCMC) is the name given to specific methods of sampling from a complex distribution. MCMC combines Monte Carlo with the construction of a Markov Chain in order to calculate estimates for probability distributions with high dimensions. Essentially, MCMC helps us to estimate important values within complex systems, that without it might be impossible or very impractical to calculate.



## MC

Monte Carlo is an approximation technique utilizing the random sampling of a probability distribution to estimate a fixed value. For example, if we take the circle inscribed within a square on the right and we wanted to estimate the area of the circle, we could take 20 random points within the square. We then count the points that fall within the circle (15), take their ratio to 20 and multiply it by 100 (the area of the square). We obtain an approximation of 75 square inches, comparable to the calculated value of 78.5. In this case, we could calculate the area of the circle rather easily; however, this method can be used to estimate much more complex areas.

## MC

A Markov Chain, simply put, is a sequence of occurrences in a system in which fixed probabilities let us estimate future states solely based on the current state rather than past states. So, the first MC in MCMC is what allows us to estimate a system's future conditions based on its current state.

## History

MCMC can be used to estimate the probability of different events and to integrate high-dimensional functions. The method has origins within the Manhattan Project with the creation of the atomic bomb. Scientists needed to estimate the probability of neutrons and atoms colliding and setting off a chain reaction. The vast applications of MCMC were recognized and have since been applied to many other less destructive projects.

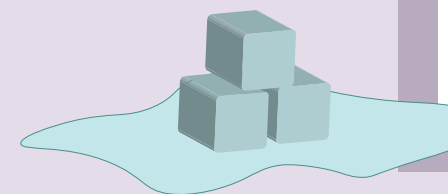


## What kinds of things can we estimate with MCMC?

With MCMC we are able to estimate values within chaotic systems that are affected by many different variables. Many nonlinear systems need special treatment due to what is commonly known as the butterfly effect, where a small change in a complex system can have much larger impacts over time. These systems are often found in the real world where many things can influence an outcome.

## Weather Conditions

MCMC has been used in weather forecasting to predict the formation of ice on roads, in order to preemptively estimate needed road work. This type of probabilistic forecasting has been shown to reduce the cost of maintenance due to weather conditions by around 50%.



Markov Chain Monte Carlo is being utilized in more than just weather forecasting. It has current applications in many fields; for example, in cryptography, solving problems which are impossible to solve using brute force.

## What does the future hold for MCMC?

Markov Chain Monte Carlo is not one specific method, but a class of algorithm. There exist many different algorithms to carry out this method. MCMC combined with other mathematical calculations is being used to predict the future states of the world around us and even human behavior. The method has grown much from where it first started and with additions to the method it continues to grow. It may have a bigger impact on the world yet.

The future of MCMC is, at this point, entangled in the future of statistics. We will no doubt see many more applications of these methods as well as their effects over the coming years.