Monte Carlo Simulation Basics

A **Monte Carlo method** is a technique that involves using random numbers and probability to solve problems. The term Monte Carlo Method was coined by S. Ulam and Nicholas Metropolis in reference to games of chance, a popular attraction in Monte Carlo, Monaco (Hoffman, 1998; Metropolis and Ulam, 1949).

Computer simulation has to do with using computer models to imitate real life or *make predictions*. When you create a model with a spreadsheet like Excel, you have a certain number of *input parameters* and a few equations that use those inputs to give you a set of *outputs* (or *response* variables). This type of model is usually **deterministic**, meaning that you get the same results no matter how many times you re-calculate. [Example 1: A Deterministic Model for Compound Interest]

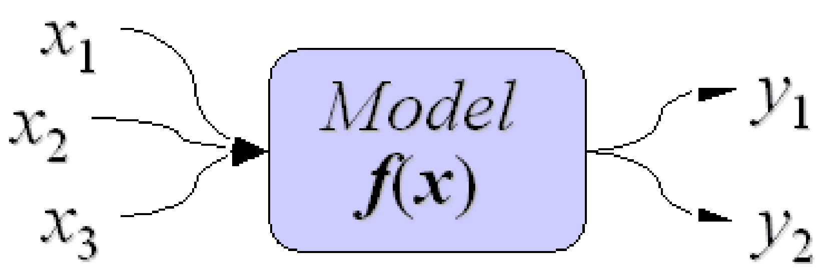

Figure 1: A parametric deterministic model maps a set of input variables to a set of output variables.

Monte Carlo simulation is a method for *iteratively* evaluating a deterministic model using sets of random numbers as inputs. This method is often used when the model is complex, nonlinear, or involves more than just a couple uncertain parameters. A simulation can typically involve *over 10,000 evaluations* of the model, a task which in the past was only practical using super computers.

Example 2: A Stochastic Model

By using **random inputs**, you are essentially turning the deterministic model into a stochastic model. Example 2 demonstrates this concept with a very simple problem.

[Example 2: A **Stochastic Model** for a Hinge Assembly]

In Example 2, we used simple *uniform random numbers* as the inputs to the model. However, a uniform distribution is not the only way to represent uncertainty. Before describing the steps of the general MC simulation in detail, a little word about *uncertainty propagation*:

The Monte Carlo method is just one of many methods for analyzing **uncertainty propagation**, where the goal is to determine how *random variation*, *lack of knowledge*, or *error* affects the *sensitivity*, *performance*, or *reliability* of the system that is being modeled. Monte Carlo simulation is categorized as a **sampling method** because the inputs are randomly generated from *probability distributions* to simulate the process of sampling from an actual *population*. So, we try to choose a distribution for the inputs that most closely *matches data we already have*, or best represents our *current state of knowledge*. The data generated from the simulation can be represented as probability distributions (or histograms) or converted to *error bars*, *reliability predictions*, *tolerance zones*, and *confidence intervals*. (See Figure 2).

Uncertainty Propagation

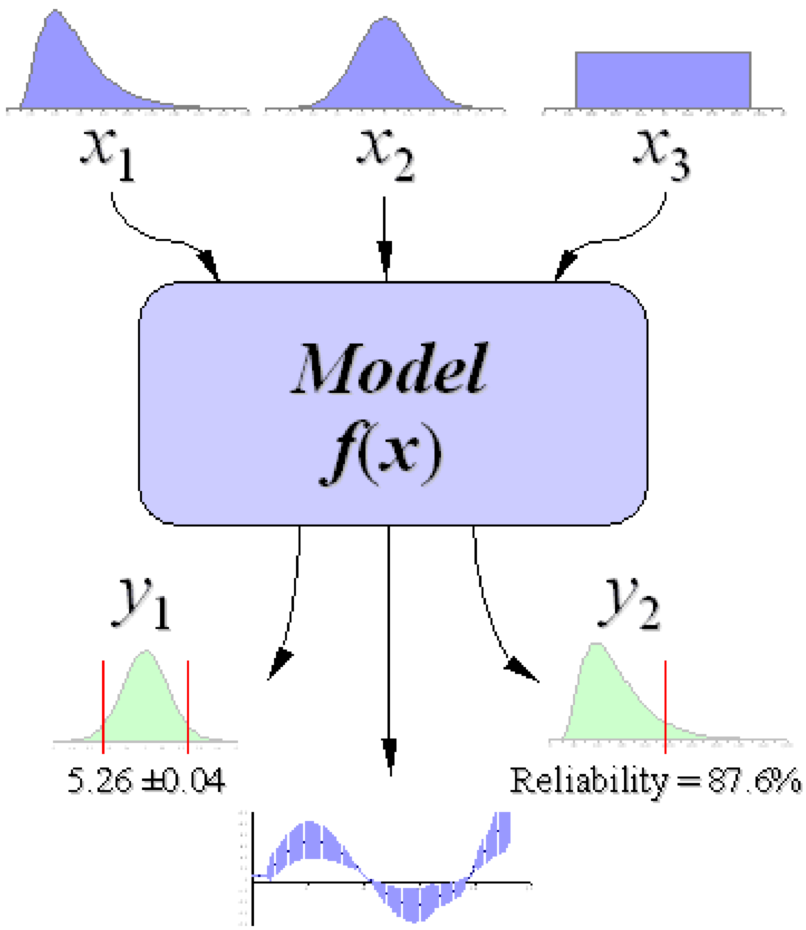

Figure 2: Schematic showing the principal of stochastic uncertainty propagation. (The basic principle behind Monte Carlo simulation.)

If you have made it this far, **congratulations**! Now for the fun part! The steps in Monte Carlo simulation corresponding to the uncertainty propagation shown in Figure 2 are fairly simple, and can be easily implemented in Excel for simple models. All we need to do is follow the **five simple steps** listed below:

Step 1: **Create a parametric model**, $y = f(x_1, x_2, \ldots, x_q)$.

Step 2: **Generate a set of random inputs**, $x_{i1}, x_{i2}, \ldots, x_{iq}$.

Step 3: **Evaluate the model** and store the results as y_i.

Step 4: **Repeat** steps 2 and 3 for $i = 1$ to n.

Step 5: Analyze the results using histograms, summary statistics, confidence intervals, etc.

On to an example problem ...

[Preface] prev next [Sales Forecast Example]

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