Monte Carlo Simulation with FORTRAN 77

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***Abstract*—This research paper introduces the concept of Monte Carlo Simulations. It offers a definition for Monte Carlo Simulations and delves into three basic principles that all implementations of these simulations have in common. It also introduces FORTRAN 77 and its importance to the scientific and engineering community. A simple example of the Monte Carlo Simulation with FORTRAN 77 code is also linked to showcase the utility of the predictive model. Lastly, an applications for the Monte Carlo Simulation is covered in structural and computer engineering.**

***Index Terms*—Monte Carlo Simulations, John Von Neumann, predictive model, FORTRAN 77, Cadence PCB Solutions**

I. The Basic Principles of Monte Carlo Simulations

Monte Carlo Simulation is a mathematical technique, invented by Jon Von Neumann, that makes predictions about undetermined events. It uses a predictive model to gain insight into the future, not literally, but by using predictive models and a variety of inputs an "educated guess" is made. Regardless of the programming language used or the implementation of the Monte Carlo Simulation, IBM describes three basic principles of this technique:

1) The setup of the predictive model, as well as the identification of the dependent and independent variables. These factors will power the prediction that results from the simulation [1].
2) A range of likely values for the prediction needs to be defined. Each possible value in the range is also assigned a weight, which is an indicator of how likely that range value is. The higher the weight of a range value, the higher the probability that it is the outcome [1].
3) The final principle is the repeated simulation with varying independent variable inputs. The more simulations that are run, the better since a more representative sample of combinations is generated. From these results, it is possible to spot trends and assess the predictions [1].

These three principles are common in various implementations of the Monte Carlo Simulations. From the results, the data can be analyzed further by determining how the predictions deviate from each other based on the inputs. In an academic paper Dr. Raychaudhuri, an industrial engineer, describes Monte Carlo Simulation as using repeated random sampling and statistical analysis as necessary components to interpret results from these kinds of simulations. He also describes this kind of analysis as a methodical way of asking "what if" analysis [2]. By changing the independent variables, the analyst sees various possibilities and what the outcomes could be for what they are testing.

Monte Carlo Simulation is typically used for predictions on finance, whether personal or looking at something more broadly like the economy, however, there are applications of these techniques in the field of engineering.

II. What is FORTRAN 77?

FORTRAN 77 is a compiled programming language. This means that the source code is converted into machine code during the compilation of the program. It is a simple yet primitive programming language. However, the machine that is code generated is highly efficient compared to most programming languages [3].

A. Why is FORTRAN 77 used for Scientific Computing?

It is a high-level programming language that is useful in scientific computing. This is because it is specifically designed for engineers and scientists who have developed expansive libraries over the lifespan of the language's existence. It is also suited for these kinds of simulations because it is easy to read and understand when compared to other programming languages because of how primitive the language is according to Roman Groger, a faculty member at the University of Pennsylvania [4]. This language has had a large user base over the years, and valuable code has been written in the language. A barrier to switching from it is translating it to a more modern language is not an easy task since the performance of the newer code may oftentimes be worse. This means that for scientists it is often more beneficial to use this language because of its simplicity, and performance.

B. FORTRAN 77 for Monte Carlo Simulations

FORTRAN 77 is one of the more commonly used versions of the language and it can be used to implement Monte Carlo Simulations. For example, one can use Monte Carlo Simulations and FORTRAN 77 to try and compute the digits of pi such as this example from Dartmouth College [5]. It showcases that generally with more simulations, the more accurate the predictions for the consecutive digits of pi are going to be. It is a simple example that showcases the utility of the Monte Carlo Simulation.

However, Monte Carlo Simulations can also be used for more complex predictions. For example, a group of structural and design engineers are using simulations to estimate the probability of failure of a non-linear structure due to seismic activity. These findings can be vital for assessing the structural design and integrity of structures. The researchers feed the predictive model with earthquake ground motion records, site-dependent ground properties, and the intensity of the seismic

activity. They are trying to predict the peak story drift ratio of structures which is a measure of the deformation and damage that is caused by the seismic activity [6].

III. Applications of Monte Carlo Simulations using FORTRAN 77 in Computer Engineering

These predictive models are proving to be an essential tool in the industry of science and engineering for making methodical predictions about wide-ranging topics from the economy to structural engineering. In computer engineering, the Monte Carlo Simulation is used in notable ways as well. This type of simulation can be used to simulate electronic circuits. Cadence PCB Solutions argues that during the simulation of electronic devices, the tolerances of the components used must be taken into account because they can have an effect on the outcome of crucial circuits. For these more crucial circuits where accuracy is important, it could be helpful to see what the possible outcomes are for different tolerances of electronic components to evaluate just how high tolerance the components used should be whether they be resistors, capacitors, or otherwise. It can be essential to the designing phase and can also be helpful for cost-benefit analysis of general systems as well where it is not crucially important for the circuit response to be so accurate. Cadence PCB Solutions allows for advanced Monte Carlo Simulations to be done in their PSpice Simulator analysis tool [7].

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