Comparison of the Monte Carlo Method and the Method of System Simulation

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Abstract: *The purpose of this study is to show some differences between the Monte Carlo method and the method of System Simulation. For this purpose, firstly, some general information has been given about simulation. Then, described briefly the Monte Carlo method and the method of System Simulation. Moreover, an application for each method has been given. Thirdly, made comparison of the two methods. Finally, talked about which method is useful and superior and in which cases these two methods can be used.*

Key words: *Simulation, Monte Carlo method, System Simulation.*

Monte Carlo Metodu ve Sistem Similasyonu Methodunun Karşılaştırılması

Özet*: Bu çalışmanın amacı, Monte Carlo yöntemi ve Sistem Simülasyonu yöntemi arasındaki bazı farklılıkları göstermektir. İlk olarak, simülasyon hakkında bazı genel bilgiler verilmiştir. Ardından, kısaca Monte Carlo yöntemi ve Sistem Simülasyonu yöntemi hakkında temel bilgiler verilmiştir. Daha sonra, her bir yöntem için birer uygulama örneği verilmiştir. Üçüncü olarak da, iki yöntemin karşılaştırılması yapılmıştır. Son olarak, bu iki yöntemin uygulamada kullanılması durumunda hangi yöntemin daha yararlı ve üstün özelliklere sahip olduğu incelenmiştir.*

Anahtar kelimeler: *Simülasyon, Monte Carlo yöntemi, Sistem Simülasyonu.*

Introduction

There are many problems in the social sciences, physical sciences, engineering, and business fields that can be stated in mathematical terms, but for which there are no analytical methods of solution. It is, as a rule, difficult to analyze complex dynamic behavior by means of mathematics, as an alternative to mathematical analysis we can turn to numerical methods to solve these problems, proceed as follows, assume some initial state or condition for the system being studied, and use whatever laws or rules of change we have in order to evaluate the states or positions some stipulated period. Increasingly, simulation is being used to study such problems. Because this type of calculation proceeds in true time-sequence, we can regard it as “simulating” or copying the behavior of the system under study. This becomes more obvious if the calculation is programmed for a computer (John Smith, 1968: 3).

1. Literature Review

1.1. What Is Simulation?

Simulation generally can be described as an approach to the numerical solution of interactive problems which are based upon a mathematical model. On the other hand, scientifically, it can be described as creating artificial random process repeating correct physical process by means of using random numbers or computer (Elbistanlıoğlu, 1988: 31).

Simulation shall used to mean the process of conducting experiments on a model of system in lieu of either direct analytical solution of some problem associated with the system (Mize et al., 1968: 1).

Many problems must be viewed in a larger context, leading to a degree of complexity beyond the ability of analytical solutions to handle. The limitations of analytical solutions were one of the factors leading to the development of simulation as a means of dealing with complex problem situations. Another motivation for the development of simulation was the desire to be able to examine the details of the dynamics of a complex operating system (Turner et al., 1993: 396).

2.1. Where Is Simulation Used?

The process of simulation involves the design and study of a model of some physical, economic, or sociological system. For example, customer service, job shop scheduling, transport problems, mechanical handling problems, maintenance problems, production buffer stocks, etc.

Simulation, which can be practiced in all areas, previously was used by Neumann and Ulam as an operational research method in solving a complex problem about the nuclear activities (Elbistanlıoğlu, 1988: 31).

Computer simulation methods have developed since the early 1960s and may well be the most commonly used of all the analytical tools of management science. For example, manufacturing, health care, business process re-engineering, transport systems, defense, etc (Pidd, 2004: 1-11).

System simulation has become the most widely used tool among industrial and system engineers (Turner et al., 1993: 396).

1.3. What Advantages Does Simulation Provide?

For the purposes of the present chapter, simulation may be taken to mean constructing a mathematical model of a physical system. The advantages of having such a mathematical model will now be made clear. Suppose it is proposed to change an existing production line by installing new machinery or employing extra staff at various stages. Such changes will involve considerable expenditure and it would be very useful to estimate in advance the effect these changes will have on the production line. Simulation enables us to do this (Thomas, 1979: 1).

As the cost of computation continues to fall, it is becoming economical for more and more system to be studied by simulation rather than by direct mathematical analysis (Forrest, 1970: 1).

To be sure, simulation methods are used more broadly than in “deriving a solution” from a mathematical model of a process. The expressed purpose of certain simulation studies is to provide a means of observing the behavior of the components of a system under varying conditions. No “solution”, in the mathematical sense, is sought; rather, the objective is to gain an understanding of the relationships among components of the system (Mize et al., 1968: 2-3).

Simulation has an expanding role in many aspects of industrial production, including research, design, operations, maintenance, and regulatory compliance (Liptak, 2006: 235).

2. The Simulation Methods

2.1. Monte Carlo Method

The class of variance – reducing techniques that known as “Monte Carlo” techniques, which rely not on statistical analysis of the input and output variables of a simulation but on reorganization of the simulation itself. Numerous techniques have been proposed for increasing the sampling efficiency of the Monte Carlo simulations above that obtainable with simple random sampling (Thomas, 1969: 252-263).

The Monte Carlo method is a way of performing numerical integrations of functions that are impossible with direct analytical approaches. The Monte Carlo method uses these approaches with random numbers (Pidd, 2004: 45-48).

Monte Carlo methods are sampling methods; therefore, the estimates that result from Monte Carlo procedures have associated sampling errors. The fact that the estimate is not equal to its expected value (assuming that the estimator is unbiased) is not an error or a mistake; its just a result of the variance of the random (or pseudorandom) data. Monte Carlo methods are experiments using random data. The variability of the random data results in experimental error, just as in other scientific experiments in which randomness values of the estimator of interest (Gentle, 2003: 235).

2.1.1 The Principles

2.1.1.1 Random Sampling

The “random numbers” used in simulation have been “random” in every respect which in practice means passing all the tests usually applied to a random number generator.

A random number variable is a numerically valued variable defined on a sample space. For each point of the sample space the random variable would be assigned a value. The random variable may be positive or negative, it may have the same value at different points of the sample space, it made discrete or continuous, and so forth. Theoretically, the set of values that such a random variable would have consists of zero and the natural numbers (Mize et al., 1968: 22).

Simulations that use sequences of random numbers and which are independent time, such as use of random numbers to evaluate definite integrals, are called Monte Carlo simulations (Stewart, 2009: 680).

2.1.2 Kinds Of problem

Dating from the 1940s, Monte Carlo methods were used to evaluate definite multiple in mathematical physics. There is now a resurgence of interest in such methods, particularly in finance and statistical inference (Daspunar, 2007: 1).

Some have been applied in particle – physics applications with outstanding success. Some have been applied to simple examples of operational problems. Monte Carlo method is usually used for problems whose distributions are not known. For example, to determine the optimal number of repair.

2.1.3 Solutions

When applied to rather artificial problems of mathematics and physics, techniques like these have produced very impressive results; one does not expect to be so impressed when one applies them to problems filled with awkward details and special cases, of the type arising in the simulation of real life, yet is still possible to gain enough efficiency to make them worth considering (Naylor, 1969: 262).

2.1.4 An Application

This application is for determining optimum number of repairmen (Mize et al., 1968: 100-103). We would minimize one cost at the expense of the other; that is, we would minimize salaries by employing only one repairman and letting broken–down machines wait their turn. Or we would minimize the cost of machine downtime by hiring so many repairmen that a machine could always receive attention immediately. Our objective, however, is to minimize the total of the two opposing costs.

We can express this relationship as follows:

$$TC_k = (\$6)(k)(h) + (\$50)(DT) \quad \text{..............}(1)$$

Where;

TC: total cost,

k: number of repairmen employed,

h: (1) number of hours of simulated operation or
(2) number of hours from beginning of simulation until last breakdown is repaired, whichever is larger,

DT: number of hours of downtime.

We specify h and we very k. Since DT is a function of h and k, we should construct our simulation model so that it will determine DT for a constant h and varying k. Let us consider the specific steps involved in simulating from the two distributions simultaneously, one distribution being dependent upon the other. It will be instructive to use the graphs in Figure 1.

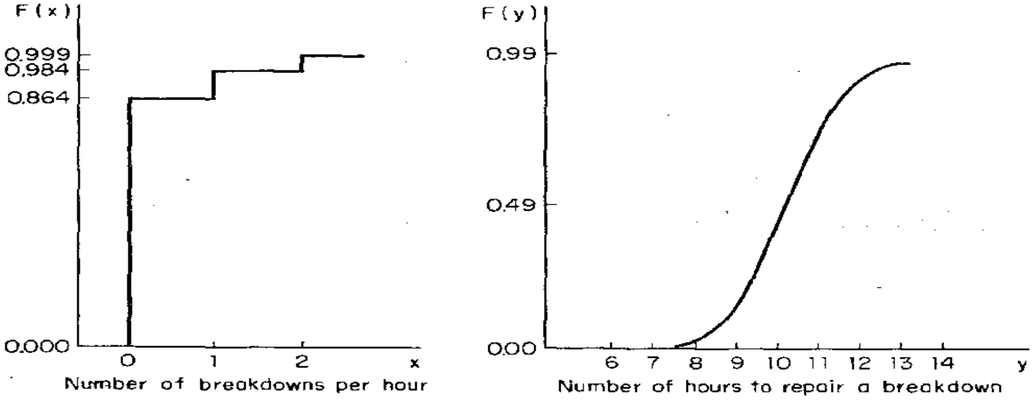

Figure 1: Graphs for Monte Carlo sampling of machine repairman problem.

A source of random numbers is needed to perform this simulation, either manual or a computer. We simulate the performance of the machine system by comparing a sequence of random numbers between 0 and 1 to the F(x) axis in Figure 1. The resulting x value corresponding to each random number is considered to represent the performance of the machines for one hour. Once a breakdown is encountered, then and only then distribution of repair time sampled. This is accomplished by using a different sequence of random numbers for the repair time distribution.

Sequence 1 (for x):

149, 880, 885, 273, 317, 677, 702, 996, 070, 838

Sequence 2 (for y):

56, 09, 05, 59, 98, 25, 48, 62, 69, 56

The results of performing a Monte Carlo simulation for ten hours of operation using the above sequences of random numbers are shown in Table 1. The amount of waiting time resulting from having one, two, and three repairmen is also shown.

Table 1: Results of Monte Carlo simulation

(1) Hour of Operation	(2) Breakdown No.	(3) Repair Time	(4) Start Repair No. of Repairmen			(5) End Repair No. of Repairmen			(6) Waiting Time No. of Repairmen		
			1	2	3	1	2	3	1	2	3
1	–										
2	1	10.1	3*			13.1					
3	2	8.7	13.1	4*		21.8	12.7		8.1		
4	–										
5	–										
6	–										
7	–										
8	3	8.2	21.8	12.7	9*	30.0	20.9	17.2	12.8	3.7	
8	4	10.3	30.0	13.1	12.7	40.3	23.4	23.0	21.0	4.1	3.7
9	–										
10 etc.	–										

* Breakdown occurred at the end of the hour of simulation. Repair starts at the beginning of the following hour.

We would need to simulate several hundred hours of operation in order to generate sufficient data to determine the optimum number of repairmen to employ. After doing this, we would add the total amount of machine down–time (repair time plus waiting time) to determine DT in Equation (1). We then calculate total cost for each policy, using Equation (1). The policy resulting in the lowest TC value should be chosen as the optimum policy.

2.2. The Method of System Simulation

In this method, experimental operation is principle and examples are chosen from real life. That is why, there are not used a theoretical community or an other like this in the method of System Simulation (Elbistanlıoğlu, 1988: 32).

2.2.1 The Principles

At the simulation application, project of the system and solutions of the system must be solved for solution of the problem (Elbistanlıoğlu, 1988: 32).

This method is used when distributions of the problem are determined and described.

2.2.2 Distributions

There are some distributions whose characteristics are known. They are mean and variance.

Some of these distributions are as follows (Mize et al., 1968: 37-51):

- Bernoilli distributions,
- Binomial distributions ,
- Hypergeometric distributions,
- Poisson distributions,
- Uniform distributions,
- Normal distributions,
- Chi-square distributions,
- t distributions,
- Exponential distributions.

2.2.3 Kinds of Problem

The method of System simulation is used for some problems which have a distribution that its characteristics are known. For example, a "periodic queuing system."

2.2.4 Solutions

By this method, a problem's characteristics in order to using some real knowledge and if the problem have a distribution known, this problem is solved.

2.2.5 An Application

This example is about handling operations at a container ship berth (John Smith, 1968: 80-86):

Many handling schemes have been suggested for the loading and unloading of container ships-that is, ships specially designed to carry containerized freight. It was felt necessary to make a comprehensive study of the various possibilities, so that guide-lines could be developed to assist individual port authorities in choosing the most suitable the most suitable scheme for their purposes.

One of the most important factors affecting the economics of container-ship operation is the utilization of ships. When designing port facilities, therefore, it is necessary to ensure that quayside handling operations can be carried out as smoothly and as rapidly as possible, with the minimum of interference between different items of handling plant. The handling scheme to be modelled was as follows.

The containers for loading (export containers) are arranged in pre-set order on a quayside park. When the ship arrives, the first operation is to unload the deck containers and convey them to spaces reserved for them in the park. Then the hold hatch covers are removed, and the next operation is to unload the containers in the hold. These are also conveyed to spaces in the park. At the same time the export containers referred to above are taken from the park and conveyed to the ship for loading into vacant spaces in the hold. In this way loading and unloading take place simultaneously, compressing the turn round time and making full use of the handling machinery. The last operation, after replacing hatch covers, is to load export deck containers. The general scheme is shown in Figure2.

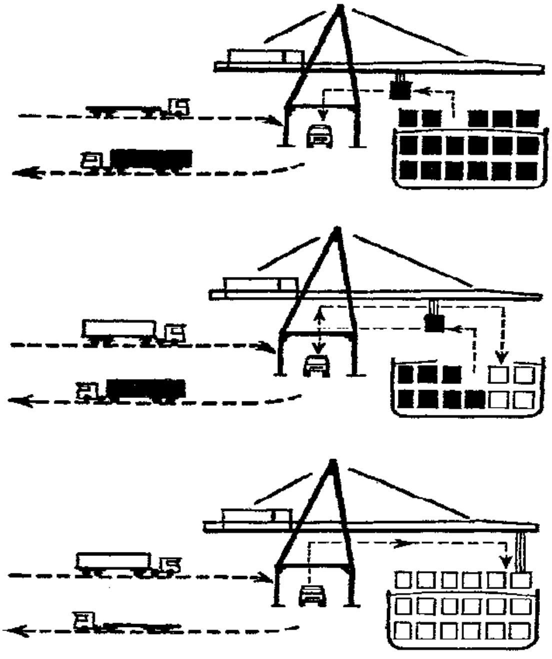

Figure 2: Three handling cycles in container-ship turn around.

There are two resources or items of equipment:

1) quayside gantry cranes of the transporter type, and

2) carriers (tractor – towed trailers).

Each of these follows a cycle of operation. The container lifting gear of the crane moves back and forth between the hold of the ship and the quay. The carrier moves back and forth between the quay and the container park. The way in which these two cycles interlock is shown in Figure 4.

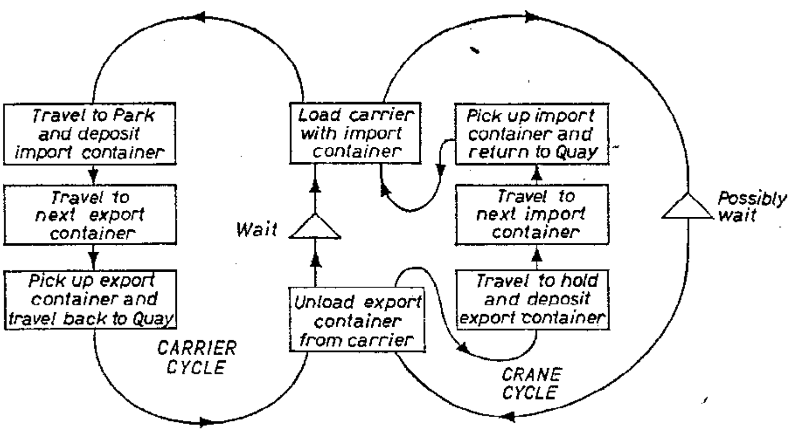

Figure 3: Container-ship turn around model

There are two co-operative activities which take place when containers are being exchanged between carrier and crane, the export container being loaded into the ship, the import container being placed on the carrier. The other activities are simple operations involving only one or other of items of equipment.

One of the objects of this present study was in fact to see how many carriers would be required to keep the quayside cranes busy without too many periods of waiting. Our approach was to construct the simulation model, then perform runs with different numbers of carriers available, and study (a) the overall turn round time, (b) the waiting time of the crane, and (c) the waiting time of the carriers. The queue length was not important because with the numbers of carriers we were using (2, 3, and 4), congestion on the quay would never hamper operations.

The model:

The model was divided into three parts, performed successively, corresponding to the three phases of the turn round operation, namely:

1) Unloading deck cargo – a one-way operation involving import containers only;

2) Unloading and loading the hold – a two-way operation involving both import and export containers; and

3) Loading deck cargo – a one-way operation involving export containers only.

Only one crane was considered in the model.

On completion of the first phase of the turn round, the next, two-way, phase was commenced in the simulation. This was represented in a similar fashion, with two-co-operative events instead of one. The third phase followed which again consisted of one co-operative event.

The time advanced in fixed six-second time–steps for the sake of simplicity.

Results:

At the onset of the study it was proposed to arrange the park in three sections, corresponding to the three successive phases of the operation (see Figure 4), as follows.

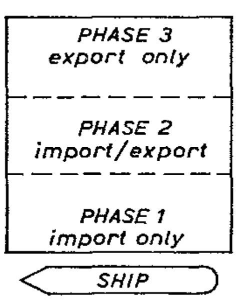

Figure 4: Original layout of quayside park

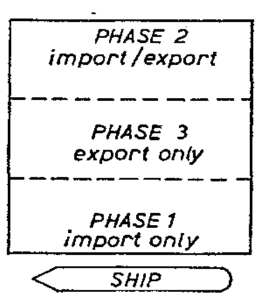

Figure 5: Final layout of quayside park

By simply re-arranging the park (see Figure 5) so that phase (3) containers were allocated the space immediately behind phase (1) containers, a better balance in cycle-times could be obtained, with consequent shortening of the overall duration of turnround.

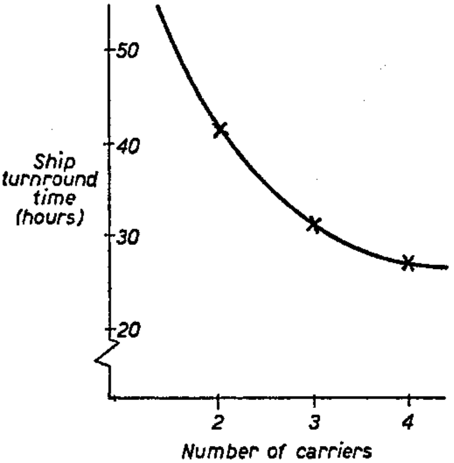

Figure 6: Relationship between number of carriers and ship turn round time

When data specifying the travel times relating to this new park layout had been punched into cards ready for computer input, runs were made with the model to study the relationship between number of carriers and ship turn round time. The crane working speeds were varied to see what effect different assumptions would have on the result. Figure 6 shows a typical example of the relationships we obtained.

These results were passed to individual port authorities so that they could assess their own needs in regard to carriers on their berths, taking into account on one hand the cost of carriers and on the other the need to achieve rapid, delay free ship turnrounds.

3. Comparison of the Two Methods

In this paper, we told briefly about two methods of simulation which are the Monte Carlo method and the method of system simulation. The Monte Carlo method is easier than the method of system simulation and it can use for every simulation problems, but it is use theoretical data for the real-life. However, the method of system simulation is use real data. This is the reason to use this model. Its risk is least than the Monte Carlo method. At the application of system simulation's method, however, project and analysis of the system is must be done. That is why it needs more long time for solution of the problem. There is also an analytic solution of the problem in the method of system simulation.

Conclusion

At the beginning to solve a problem with simulation, the content of the problem should be viewed primarily. If the problem's data set can be obtained easily, the method of system simulation is used to solve the problem. When the problem's characteristics are described and its distribution is the same distribution known, the method of system simulation is very useful. However, if a problem's content and behavior cannot be observed, we use the Monte Carlo method. Moreover, at the beginning of a problem, in troublesome cases of the problem's data set creation; we can use the Monte Carlo method. In this way, we can guess the solution of the problem until the real solution is made with the method of system simulation.

Simulation could be done on the computer very easy, in several seconds. As simulation models get progressively more complex, making the computer a necessity. The first step developing a simulation model is to generate random numbers, which are between 0 and 1. Random numbers can be generated in Excel by entering the formula, "= RAND ( )". Simulation is one of the most popular all of quantitative techniques because can be applied to operational problems that are too difficult to model and solve analytically. Some analysts feel that complex systems should be studied via simulation whether or not they can be analyzed analytically, because it provides an easy vehicle for experimenting on the system. Surveys indicate that a large majority of major corporations use simulation in such functional areas as production, planning, engineering, financial analysis, research and development, information systems, and personnel (Russell, 200; 634-640).

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