OPTIMIZING TOOL DISPENSATION FROM METALLURGICAL STORE THROUGH MONTE CARLO ALGORITHM BASED SIMULATION

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Abstract

With the development of computers and software products, there is now greater use of quantitative methods in industrial enterprises when making managerial decisions. One of the most applicable solutions to computer simulation algorithms is the Monte Carlo method. The application of the Monte Carlo algorithm lies in finding a relation between the individual variables, which are the solutions to the problem and represent the characteristics of random processes reproducible on computers. The Monte Carlo algorithm is well applicable in a variety of metallurgical production processes. Metallurgical processes have different specifics with which to be reckoned with, eg. prioritizing service workers when dispensing tools from maintenance men.The aim of this article is to show the application of simulations from the Monte Carlo algorithm using the example of optimising tool dispensation from metallurgical store.

Keywords: Management science, optimisation, simulation, Monte Carlo algorithm

1. INTRODUCTION

One of the most useful roles of the Monte Carlo simulation is solving of problems of waiting or queuing [1]. Analytical solutions become extremely difficult or even impossible when dealing with somewhat complicated waiting tasks, e.g. when the arrival rate or service times do not correspond to the standard distribution (Poisson), or when priorities are being considered [2].

2. THEORETICAL BACKGROUND

Monte Carlo methods use the computer together with the generation of random numbers and mathematical models to generate statistical results that can be used to simulate and experiment with the behavior of various business, engineering and scientific systems. Some examples of application areas where Monte Carlo modeling and testing have been used are: the simulation and study of specific business management practices, modeling economic conditions, operations research, information processing, analysis of mass production techniques, analysis of traffic flow and simulation of press and sinter powder metallurgy processes [8].

Monte Carlo simulations usually employ the application of random numbers which are uniformly distributed over the interval [0, 1]. These uniformly distributed random numbers are used for the generation of stochastic variables from various probability distributions. These stochastic variables can then be used to approximate the behavior of important system variables. In this way one can generate sampling experiments associated with the modeling of system behavior. The statistician can then apply statistical techniques to analyze the data collected on system performance and behavior over a period of time. The generation of a system variable behavior from a specified probability distribution involves the use of uniformly distributed random numbers over the interval [0, 1]. The quantity of these random numbers generated during a Monte Carlo simulation can range anywhere from hundreds to hundreds of thousands. Consequently, the computer time necessary to run a Monte Carlo simulation can take anywhere from minutes to months depending upon the both the computer system and the application being simulated. The Monte Carlo simulation produces various numerical data associated with both the system performance and the variables affecting the system behavior. These system variables which model the system behavior are referred to as model parameters. The study of the sensitivity of model parameters and their affect on system performance is a large application area of Monte Carlo simulations [7].

3. OPTIMISING EMPLOYEES IN THE METALLURGICAL STORE

Metallurgical company uses a central tool store from which the tools are dispensed to the employees. Let us consider a typical situation with one tool store employee. The store serves two groups of employees: production workers and maintenance workers. Both groups have different arrival rates, as shown in **Table 1**. Note that the arrival rates do not correspond to the standard distribution. **Table 1** also includes the Monte Carlo numbers which are needed for the simulation. The number of employees in both groups is large enough to consider the source of arrivals to be infinite [6].

Table 1 Arrival Rate

Production workers			Maintenance workers		
Interval between arrivals (hrs.)	**Probability**	**Monte Carlo number(s)**	**Interval between arrivals (hrs.)**	**Probability**	**Monte Carlo number(s)**
0.2	0.1	0	0.4	0.25	00-24
0.3	0.1	1	0.6	0.60	25-84
0.5	0.4	2-5	1.0	0.15	85-99
0.8	0.3	6-8			
1.0	0.1	9			

Normally, the production workers have priority over the maintenance workers, i.e. a production worker will always be put to the head of the waiting queue. In case a maintenance worker is already being served, the operation will not be interrupted (i.e. the production employee priority is not enforced).

Table 2 shows the distribution of service times, while there are only three values assumed: 0.1, 0.2 and 0.3 hour. **Table 2** also contains the Monte Carlo numbers.

Table 2 Service Times

Service duration (hrs.)	Probability	Monte Carlo numbers
0.1	0.33	000-332
0.2	0.33	333-665
0.3	0.33	666-998

The perfect use of the one-third shares would be consistent with the use of 999 out of the 1000 three-digit numbers [3]. If a number is not used (e.g. 999 in **Table 2**) while being one of the Monte Carlo numbers, it is simply skipped [4].

The storekeeper earns CZK 100 per hour; a production worker is paid CZK 125 per hour and a maintenance worker CZK 150 per hour. The challenge is to find the optimal number of employees in the tool crib. The management also wants to know whether the existing priority handling should be kept [5].

Table 3 Generation of Arrivals (No. 1 arrives at 7:00)

Production workers				Maintenance workers		
Arrival No.	Random number	Time between arrivals (hrs.)	Time (hrs.)	Random number	Time between arrivals (hrs.)	Time (hrs.)
2	5	0.5	7:30	52	0.6	7:36
3	2	0.5	8:00	02	0.4	8:00
4	0	0.2	8:12	73	0.6	8:36
5	2	0.5	8:42	48	0.6	9:12
6	7	0.8	9:30	06	0.4	9:36
7	3	0.5	10:00	15	0.4	10:00
8	4	0.5	10:30	94	1.0	11:00
9	8	0.8	11:18	12	0.4	11:24
10	0	0.2	11:30	95	1.0	12:24
11	6	0.8	12:18	87	1.0	13:24
12	1	0.3	12:36	04	0.4	13:48
13	5	0.5	13:06	99	1.0	14:48
14	9	1.0	14:06	40	0.6	15:24
15	4	0.5	14:36	98	1.0	16:24

4. SIMULATION

4.1. Arrival Simulation

Arrivals of 15 employees of both groups were simulated. For that, random numbers generated by MS Excel have been used. The results are shown in **Table 3**; the table also contains the arrival times.

Let us assume the employee No. 1 arrived at the beginning of the opening period at 7:00. For the arrival of the second employee, a random single-digit number 5 is generated. According to **Table 1** for manufacturing workers, the random number 5 falls within the range of 2-5, which corresponds to 0.5 hrs. between arrivals. Since the process starts at 7:00, the time of arrival is 7:30. The arrival generation continues. For the third production worker a random number 2 is generated. The time between arrivals is again 0.5 hrs. arrival time is 7:30. we add 30 minutes and the resulting time is 8:00. The generation process continues for the required number of 15 arrivals (**Table 3**) or for a specific time period. When the arrivals of the production workers have been generated, the arrivals for the maintenance workers are generated using different (two-digit) random numbers.

4.2. Simulation of Service Times

These times are generated using three-digit numbers and **Table 2**. The method is analogous to the generation of arrivals. The results are shown in **Table 4** with 30 generated services. A different set of random numbers is used.

Table 4 Generation of 30 Services

Service number	Random number	Service duration (hrs.)	Service number	Random number	Service duration (hrs.)
1	782	0.3	16	978	0.3
2	309	0.1	17	477	0.2
3	194	0.1	18	752	0.3
4	308	0.1	19	016	0.1
5	421	0.2	20	579	0.2
6	392	0.2	21	260	0.1
7	283	0.1	22	241	0.1
8	682	0.3	23	643	0.2
9	871	0.3	24	056	0.1
10	744	0.3	25	861	0.3
11	244	0.1	26	565	0.2
12	773	0.3	27	029	0.1
13	264	0.1	28	970	0.3
14	283	0.1	29	958	0.3
15	879	0.3	30	713	0.3

4.3. Process Simulation

Suppose a production worker and a maintenance worker wait in front of the tool crib at 7:00. The production worker is served first (has priority). **Table 4** indicates (based on the first random number 782) a service time of 0.3 hours (18 minutes) from 7:00 to 7:18. During this period the maintenance worker waits. The second production worker arrives after 30 minutes at 7:30 according to **Table 3.**

The first maintenance worker will be served at 7:18. This operation will end at 7:24 (random number 309 for the service time of 0.1, which is equal to 6 minutes in **Table 4**). The second production worker arrives at 7:30 and is served from 7:30 to 7:36. The second maintenance worker arrives at 7:36 (random number 52 means the second maintenance worker arrives 0.6 hours after the first one, see **Table 4**). Because there is no queue in front of the tool crib, this worker is served immediately (the operation takes 0.1 hours according to **Table 4**). The third production worker and the third maintenance worker both come at 8:00. Due to the priority the production worker is served first. The third production worker is served for 0.2 hrs., from 8:00 to 8:12. The arrival of the fourth production worker follows, and because of the priority he is served before the third maintenance worker.

5. CALCULATION OF CHARACTERISTICS AND SYSTEM EFFICIENCY MEASURES

The six-hour process simulation should continue until reaching stabilization. For our purposes, we will determine the results from the six-hour simulation.

5.1. Arrivals

Ten maintenance workers arrived at the tool crib, i.e. an average of 10/6, equivalent to 1.67 per hour. 12 production workers arrived, or 12/6, equivalent to 2 per hour.

5.2. Service

All 22 persons have been served. The total service time was 4.2 hours. The tool dispenser utilization was 4.2/6, equivalent to 70 %. The average service time was 4.2/22, equivalent to 0.19 hours.

5.3. Probability of Waiting

Of the 10 maintenance workers, 5 had to wait for service. Thus, the probability that the maintenance worker must wait is 5/10, equivalent to 50 %. Only one of the 12 production workers had to wait, which is 1/12, equivalent to 8.34%.

5.4. Queue Length

The total waiting time was 1.5 hours. The average per employee is 1.5/22, equivalent to 0.07 hours (approx. 4 minutes). The average waiting time for maintenance worker was 1.3/10, equivalent to 0.13 hours, against waiting time for production worker 0.2/12, equivalent to 0.02 hours.

5.5. Total Waiting Costs

Production workers: 0.2 hr. x CZK 125 = CZK 25 for six-hour period

Maintenance workers: 1.3 hr. x CZK 150 = CZK 195 for six-hour period

Total waiting costs: CZK 220 for six-hour period

Hourly waiting costs are 220/6 = CZK 36.67

Priority - in five cases (50 % of all maintenance workers) the production workers exercised their priority.

6. CONCLUSION

The system in this case appears to be effective. The waiting costs are CZK 36.67 per hour. At a cost of CZK 100 per hour, it would not make sense to add another tool dispenser for the store, because the maximum possible saving is CZK 36.67 per hour. As regards the priority of the production workers, new simulation would have to be run with a first come - first served rule, and the results compared. Also running a third simulation would be possible, with priority given to the maintenance workers (their hourly wages are higher), and the results compared.

In other systems the waiting queue could be longer and waiting costs very high. In such a system a simulation could be run to determine the justification of two or three tool dispensers. In the case of adding one or two tool dispensers, these workers can work in a different configuration, e.g. each tool dispenser could serve only one group of employees or both could serve one person (one to perform administrative tasks, the other to dispense the tools). Simulation resolves all these cases quickly.

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