Home assignment 2, Simulation

Let each task be in one section of the report. At the end of the report, append the code for the programs. Put everything in one **pdf** file. Also submit the source code for test runs in a zip archive where each task is separated onto folders. A report template is provided together with the assignment specification.

The purpose of this home assignment is to practice writing simulation programs using the event scheduling approach and the process interaction method. You will also study verification and validation of simulation programs and interpret the statistical validity of your results using confidence intervals.

Some general hints

When writing a simulation program using the event scheduling approach it is often of great help to start by answering the following questions:

- What variables are needed to describe the state of the system? Do not use a more complicated state description than needed.
- What events are needed?
- What shall be done when a certain event takes place? Use flow diagrams, pseudo code or write it down in words.

When writing a simulation program using the process interaction method the following questions should be answered before you start coding:

- What process classes are needed?
- What signals are needed?
- What variables are needed in the process classes?
- What shall a process do when it receives a signal?

Usually one has to iterate these questions several times. Remember that minutes spent on these questions can save hours of work later on! When you have answered these questions, the translation to a simulation program is (in principle) straightforward.

Task 1

Here you shall study the transient phase of a simulation and find confidence intervals.

The system you shall simulate works as follows: arrivals come to the system in accordance with a Poisson process of rate λ per second. The inter-arrival distribution is therefore negatively exponential. There are N parallel servers in the system. The service time of a customer is x seconds. There is no buffer in the system, which means that if all servers are busy when a customer arrives the customer is rejected. We also set T = the time between measurements and M = number of measurements that should be done. Write a simulation program for this system and do the following:

1. Let $N = 1000$, $x = 100$, $\lambda = 8$, $T = 1$ and $M = 1000$.Write the number of customers in the system at each measurement in a file and use matlab (or any other graphing software) to plot the number in the

system versus the measurement. Use the command 'load' to read a file into matlab and then 'plot' to plot the data. How long is approximately the transient phase?

2. Run the program again but change x to 10 and increase λ to 80. How long is the transient phase now? Observe that the mean number of customers in equilibrium is the same as in 1 above.
3. Now increase x to 200 and reduce λ to 4. How long is the transient phase in this case? Observe that the mean number of customers in equilibrium is the same as in 1 and 2 just above.
4. Now we shall see how the number of measurements and the distance between them affects the accuracy of the simulation. In 4, 5 and 6 we set $n = 100$, $x = 10$ and $\lambda = 4$ but we let T and M vary. First let $T = 4$ and $M = 1000$ and find the length of the 95 % confidence interval.
5. It is tempting to make the times between measurements shorter. Let $T = 1$ and $M = 4000$. How long will the confidence interval be? Explain the result.
6. Let now $T = 4$ again and let $M = 4000$. How long is the confidence interval? Explain the result.

Task 2

Consider a pharmacist who is thinking of setting up a pharmacy where they will fill prescriptions. They plan to open at 9.00 every weekday. No new prescriptions are accepted after 17.00. During the opening hours customers come according to a Poisson process with rate 4 per hour. The time it takes to fill a prescription is uniformly distributed between 10 and 20 minutes. The prescriptions are always handled in a FIFO manner. After 17.00 they have to continue working until all prescriptions that have arrived during the day are filled. Use simulation to answer the following questions:

a) What is the average time when their work will have finished every day? Use 95% confidence intervals

b) What is the average time from the arrival of a prescription until it has been filled? Use 95% confidence intervals

Observe that you have to simulate many working days to be able to answer the questions! Simulate at least 1000 working days but even more if you think the confidence intervals are too big.

Task 3

You are a private investor who has a goal of saving up money to buy a brand spanking new sail boat. You want to invest in a high risk share and you perform a time series analysis of the previous behaviour of the share with the following findings:

The growth of the share is constant at 30 % per annum (over a normal year).

Some years, there is a market disturbance that causes some investors to sell their shares rapidly. The mechanism seems to work as follows:

In 10% of the cases, 25% of the share holders sell causing a drop in value of 25%

In 25% of the cases, 40% of the share holders sell causing a drop in value of 50%

In 15 % of the cases, 50% of the share holders sell causing a drop in value of 60%

In all other cases, no shares are sold but the value drops 10 %

The disturbances seem to be uniformly distributed with an average 4 years between.

You save a fixed amount per month and the interest on the accumulated balance is added once every month. Assume that the growth rate is constant over the year.

Find out the expected time to save up two million kronor and plot with a 95% confidence interval in the following cases. Every month you save:

[5, 10, 20] thousand kr.

a) Plot the number of months it takes to buy the boat for each savings level and simulate until the confidence intervals are no larger than two months.

b) Now discuss this result. Can you trust this result? Why can you or can't you? Is the result valid regardless of when in time you start saving? What are the error sources in this exercise and how may they affect the reliability of the study? Finally, discuss if this task has a good or bad specification. Do you have to make assumptions, is the system too simplified, is this kind of study useful when deciding to make the purchase? Reflect over the relative merits, pros and cons of this kind of study.