

Chapter 6

Random and Exogenous Variation in the Model

Random and exogenous sources of variation play a central role in discrete event simulation. The Sampler, Server, MServer, and formulas are the principle sources of this variation in the QSIM models. However, there are other situations where variation can be meaningfully incorporated into models. For example, you may want to delay the effect of a Trigger for some random or fixed amount of time. In each of these cases you have access to a combo box, such as the one in the Sampler control panel shown in Figure 6.1, labeled to show the use of the source of variation. In this case, it is the time between transaction arrivals to the system. If you click on the down arrow, a list that includes the possible distributions is displayed.

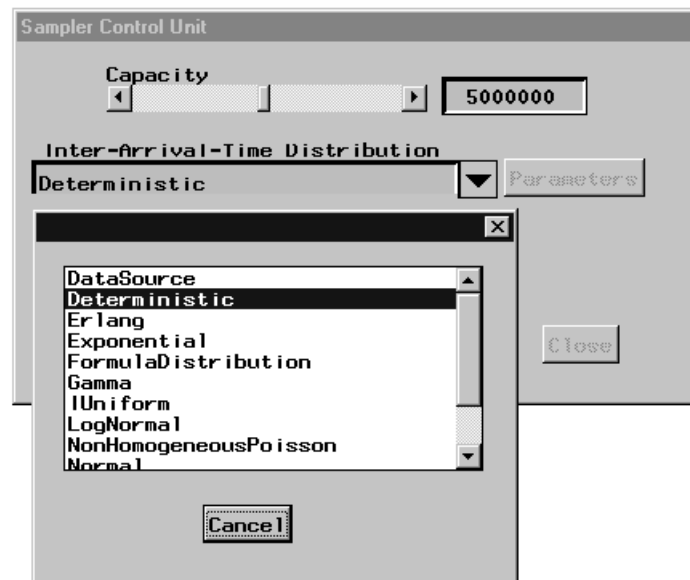


Figure 6.1. Sources of Variation

When you select one of these distributions, the selection is displayed in the text area to the left of the down arrow. For each distribution you select, you can set one or more parameters which further define the choice.

There are two types of sources of variation: random and exogenous. These are not mutually exclusive. That is, an exogenous source of variation can be randomly generated.

Random Sources of Variation

The random sources of variation are generated using pseudo-random number generators. The QSIM application provides a set of standard generators. These include:

- Exponential, with mean λ and density function

$$f(x) = \lambda \exp^{-\lambda x}, \text{ for } x \geq 0, \lambda \geq 0$$

- Nonhomogeneous Poisson, with rate parameter $\lambda(t)$ and density function

$$f(x) = \frac{1}{\lambda(t)} \exp^{-x/\lambda(t)}, \text{ for } x \geq 0, \lambda(t) \geq 0$$

where $\lambda(t)$ is cyclic and continuous for all $t \geq 0$ with

$$\lambda^* \equiv \sup_{t \geq 0} \lambda(t)$$

- Gamma, with parameters λ and n and density function

$$f(x) = \frac{x^{n-1} \exp^{-x/\lambda}}{\lambda^n \Gamma(n)}, \text{ for } x \geq 0, \lambda > 0, n > 0$$

- Erlang, with parameters λ and n and density function

$$f(x) = \frac{x^{n-1} \exp^{-x/\lambda}}{\lambda^n \Gamma(n)}, \text{ for } x \geq 0, \lambda > 0, n \in \mathbb{Z}^+$$

- Uniform, with parameter U and density function

$$f(x) = \frac{1}{U}, \text{ for } U \geq 0, 0 \leq x < U$$

- IUniform, with parameter U and density function

$$f(x) = \frac{1}{[U]}, \text{ for } U \geq 1, 0 \leq x \leq [U], x \in \mathbb{Z}^+$$

- Deterministic, with parameter U and density function

$$f(x) = 1, \text{ for } x = U$$

Each of these generators has a control panel for setting parameters. For example, if you pick Exponential from the list box in Figure 6.1 and then click the **Parameters** button, the exponential control panel in Figure 6.2 will be displayed. In this window, you set the initial seed value and the mean λ .

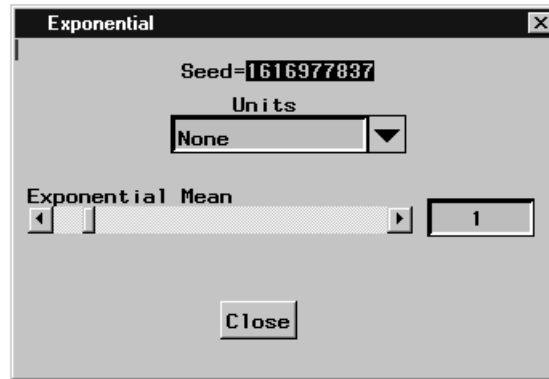


Figure 6.2. The Exponential Control Panel

The seed value for each distribution is initialized automatically. You have the capability of changing this value. The next section tells you how you can control seed values.

Note that, by default, the Exponential mean in Figure 6.2, is set to 1. You can change the mean with the slider. The slider has a range of 0 to 10 for this parameter. If 10 is not large enough for the mean, you simply click in the display and type the mean that you want.

Controlling the Seed Values

The QSIM application gives you considerable control over the streams of random numbers used in simulations. Each instance of a random number has its own unique generator. The control panel for each provides a mechanism for setting the seed and time units associated with the random variable. The exponential control panel in Figure 6.2 shows this. By default, a seed is selected when the component is instantiated. This seed is selected from a seeds dataset, named QSEEDS, in the SASHELP library and selected to guarantee no overlap with any other random variable seed values for 100,000 observations. Moreover, each time you run the QSIM Application, the selection of seeds continues from where it last left off. You can control these by raising the Seed Control panel by selecting the **Options** ► **Seeds...** from the pull-down menus (see Figure 6.3) on the Simulation window.



Figure 6.3. The Options Pull-down Menu

In the **Seed Preferences** window, shown in Figure 6.4, you can increase the default distance between seeds, and when you click the **Reset Seeds** button you reset the seeds to the original values that were automatically assigned when the components were instantiated. This enables you to rerun the simulation with the same seed values used initially.

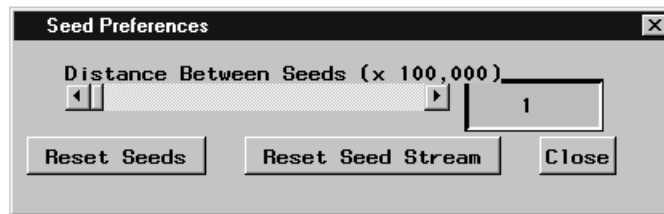


Figure 6.4. The Seed Control Panel

The **Reset Seed Stream** button resets the seed stream to the beginning of the QSEEDS dataset. This will result in use of the seeds that were used when the application was first installed on your computer. You can also edit the QSEEDS data set in the SASHELP directory to change the seed values although this is not recommended.

Controlling Time Units

Each of the random variable control panels also shows a Units combo box. See Figure 6.2 for an example. With this you can identify a value for the time units. Then, with the Clock Options window, (see Figure 6.5) accessed by selecting **Options > Clock Options...** from the Simulation window (Figure 6.3), you can assign time units to be used for the simulation clock.

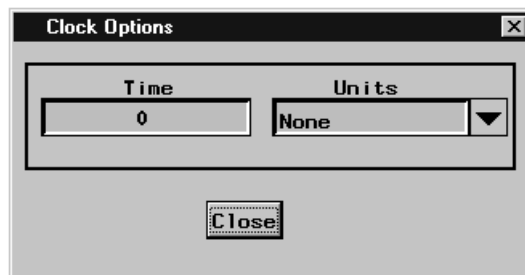


Figure 6.5. The Clock Control Panel

If you select time units for the simulation of seconds and an inter-arrival time distribution for some random variable on a Sampler has time units of minutes, then the simulation will automatically factor in the conversion in the sampling.

FormulaDistribution

QSIM provides a general function writing capability with the **FormulaDistribution** selection, shown in the list box in Figure 6.1. After you select it and then click the **Parameters** button, a Formula Manager window (as shown in Figure 4.1) is displayed. From this window, you can write a function that returns a number that is used as the sample. For example, suppose you wanted a mixture distribution with density function

$$f(x) = .5f_1(x) + .5f_2(x)$$

where $f_1(x)$ is exponential with parameter λ , and $f_2(x)$ is uniform. Figure 4.1 shows a portion of the four windows needed to express this.

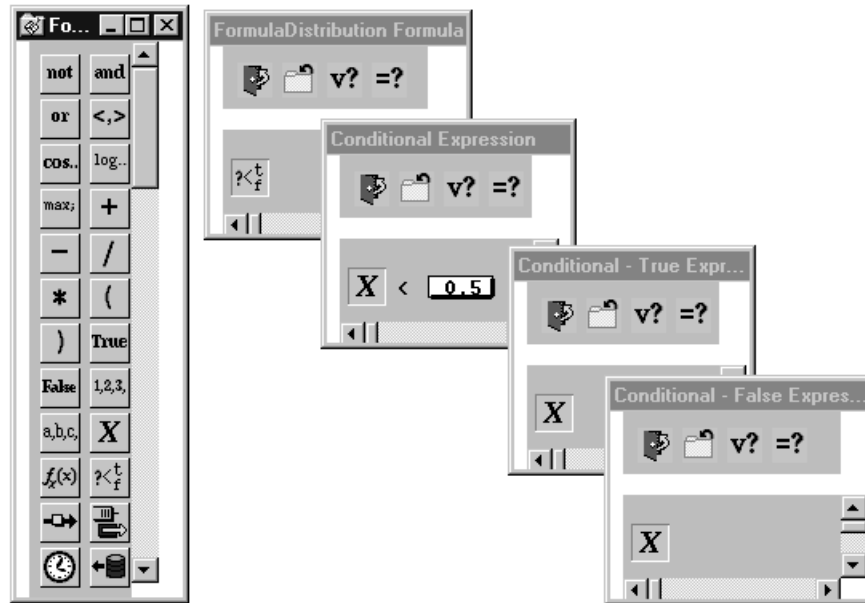


Figure 6.6. An Example of a Mixture Distribution

The bottom window is the FormulaDistribution Formula window, and it contains the conditional element $?<f$. Editing this element provides you with the capability to specify the condition $X < 0.5$. If the condition evaluates to TRUE, it returns the formula in the True Expression window X , which is the appropriate exponential random variable; if it evaluates to FALSE, it returns the formula in the False Expression window X , which is the uniform random variable.

DataSource

You have another opportunity to customize the source of variation with the **Data-Source** selection shown in Figure 6.1. With this choice, you can select a SAS data set and a numeric variable. Whenever a sample is needed, an observation is read from the data set and the value of the selected variable is used as the sample value. You choose the data set by clicking the **Parameters** button, which displays the Data-Source Control window in Figure 6.7.

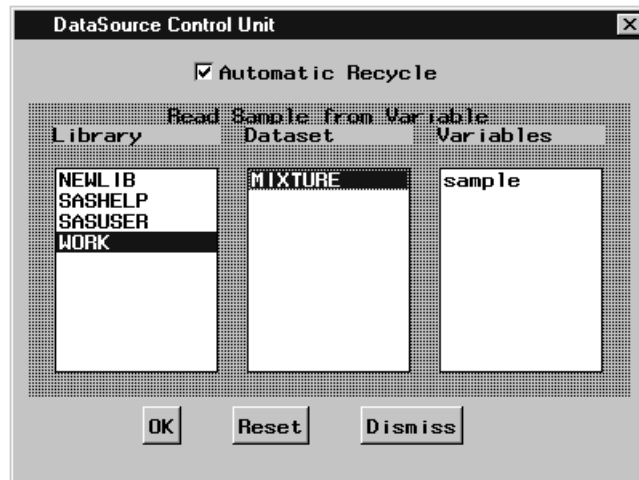


Figure 6.7. The DataSource Control

Suppose that you had executed the following DATA step which sampled 10,000 observations from the mixture distribution with density function

$$f(x) = .5f_1(x) + .5f_2(x)$$

where $f_1(x)$ is exponential with parameter 1 and $f_2(x)$ is uniform.

```
data mixture;
  keep sample;
  do i = 1 to 10000;
    if ranuni(123456789) < .5 then
      sample = ranexp(98765432);
    else sample = ranuni(54321678);
  output;
  end;
```

Then, the selections highlighted in Figure 6.7 would result in the sample being used. Note that the simulation may require more than 10,000 observations of the random variable with this mixture density. In this case, the DataSource will rewind the data set to the beginning and reuse the sample. If this feature is not accounted for, it could result in some unexpected and incorrect estimates of performance measures.

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