eservice test" to try out new policies
system, before running the risk of

uable in that they afford a convenient
ed system into subsystems, each of
nalyst or team that is expert in that

study dynamic systems in either real
ime.
troduced into a system, simulation
s and other problems that may arise
375].

s to *replicate* an experiment. Replica-
with selected changes in parameters
by the investigator. In addition,
to induce correlation between these
the statistical analysis of the output
ve correlation is desirable when the
nmed, whereas a positive correlation
differenced, as in the comparison of

model be presented in a particular
ee of freedom so that a model can
system being studied. The results
e same as observations or measure-
the system itself. To demonstrate
discrete simulation, an example of
n Section 1.4. Many programming
ating simulation languages. Some of
nile others are designed for specific
OL, and PL/1 are examples of
S, SIMSCRIPT, and SIMULA are
es.
and very versatile tool in those
e inadequate. However, it is by no
technique. It provides only *statisti-*
and it only compares alternatives
Simulation is also a *slow* and *costly*
quires a large amount of time and
mming. Finally, simulation yields
ance of the system, and sensitivity

analysis of the model parameters is very expensive. The only possibility is to conduct series of simulation runs with different parameter values.

We have defined simulation as a technique of performing *sampling experiments* on the model of the system. This general definition is often called simulation in a *wide sense*, whereas simulation in a *narrow sense*, or *stochastic simulation*, is defined as experimenting with the model over time; it includes sampling stochastic variates from probability distribution [19]. Therefore stochastic simulation is actually a statistical sampling experiment with the model. This sampling involves all the problems of statistical design analysis.

Because sampling from a particular distribution involves the use of random numbers, stochastic simulation is sometimes called *Monte Carlo simulation*. Historically, the Monte Carlo method was considered to be a technique, using random or pseudorandom numbers, for solution of a model. Random numbers are essentially independent random variables uniformly distributed over the unit interval [0, 1]. Actually, what are available at computer centers are arithmetic codes for generating sequences of *pseudorandom digits*, where each digit (0 through 9) occurs with approximately equal probability (likelihood). Consequently, the sequences can model successive flips of a fair ten-side die. Such codes are called *random number generators*. Grouped together, these generated digits yield pseudorandom numbers with any required number of elements. We discuss random and pseudorandom numbers in the next chapter.

One of the earliest problems connected with Monte Carlo method is the famous Buffon's needle problem. The problem is as follows. A needle of length l units is thrown randomly onto a floor composed of parallel planks of equal width d units, where $d > l$. What is the probability that the needle, once it comes to rest, will cross (or touch) a crack separating the planks on the floor? It can be shown that the probability of the needle hitting a crack is $P = 2l/\pi d$, which can be estimated as the ratio of the number of throws hitting the crack to the total number of throws.

In the begining of the century the Monte Carlo method was used to examine the Boltzmann equation. In 1908 the famous statistician Student used the Monte Carlo method for estimating the correlation coefficient in his t-distribution.

The term "Monte Carlo" was introduced by von Neumann and Ulam during World War II, as a code word for the secret work at Los Alamos; it was suggested by the gambling casinos at the city of Monte Carlo in Monaco. The Monte Carlo method was then applied to problems related to the atomic bomb. The work involved direct *simulation* of behavior concerned with random neutron diffusion in fissionable material. Shortly thereafter Monte Carlo methods were used to evaluate complex multidi-