**Computer simulation**

A computer simulation (also referred to as a computer model or a computational model) is a computer program, or network of computers, that attempts to simulate an abstract model of a particular system. Computer simulations have become a useful part of the mathematical modelling of many natural systems in physics (computational physics), chemistry and biology; human systems in economics, psychology, and social science, and in the process of engineering new technology. Computer simulations vary from computer programs that run a few minutes, to network-based groups of computers running for hours or ongoing simulations that run for days. The scale of events being simulated by computer simulations has far exceeded anything possible (or perhaps even imaginable) using the traditional paper-and-pencil mathematical modelling: over 10 years ago. A desert-battle simulation, of one force invading another, involved the modelling of 66,239 tanks, trucks and other vehicles on simulated terrain around Kuwait, using multiple supercomputers in the DoD High Performance Computer Modernization Program. Another simulation ran a 1-billion-atom model, where previously, a 2.64-million-atom model of a ribosome, in 2005, had been considered a massive computer simulation. And the Blue Brain project at EPFL (Switzerland) began in May 2005 to create the first computer simulation of the entire human brain, right down to the molecular level.

**Simulation versus modelling**

Traditionally, the formal modelling of systems has been via a mathematical model, which attempts to find analytical solutions to problems, which enables the prediction of the behaviour of the system from a set of parameters and initial conditions. While computer simulations might use some algorithms from purely mathematical models, computers can combine simulations with the reality of actual events, such as generating input responses to simulate test subjects who are no longer present. Note that the term computer simulation is broader than computer modelling, which implies that all aspects are being modelled in the computer representation. However, computer simulation also includes generating inputs from simulated users to run actual computer software or equipment, with only part of the system being modelled: an example would be flight simulators which can run machines as well as actual flight software. Computer simulations are used in many fields, including science, technology, entertainment, and business planning and scheduling.

**History**

Computer simulation was developed hand-in-hand with the rapid growth of the computer, following its first large-scale deployment during the Manhattan Project in World War II to model the process of nuclear detonation. It was a simulation of 12 hard spheres using a Monte Carlo algorithm. Computer simulation is often used as an adjunct to, or substitution for, modelling systems for which simple closed form analytic solutions are not possible. There are many different types of computer simulation; the common feature they all share is the attempt to generate a sample of representative scenarios for a model in which a complete enumeration of all possible states of the model would be prohibitive or impossible. Computer models were initially used as a supplement for other arguments, but their use later became rather widespread.

**Data preparation**

The data input/output for the simulation can be either through formatted text files or a pre- and post processor.

**Computer simulation in practical contexts**

Computer simulations are used in a wide variety of practical contexts, such as:

• analysis of air pollutant dispersion using atmospheric dispersion modelling

• design of complex systems such as aircraft and logistics systems

• design of noise barriers to effect roadway noise mitigation

• flight simulators to train pilots

• weather forecasting

• behaviour of structures (such as buildings and industrial parts) under stress and other conditions

• design of industrial processes, such as chemical processing plants

• strategic management and organizational studies

• reservoir simulation for the petroleum engineering to model the subsurface reservoir

• Process Engineering Simulation tools

• robot simulators for the design of robots and robot control algorithms

The reliability and the trust people put in computer simulations depends on the validity of the simulation model, therefore verification and validation are of crucial importance in the development of computer simulations. Another important aspect of computer simulations is that of reproducibility of the results, meaning that a simulation model should not provide a different answer for each execution. Although this might seem obvious, this is a special point of attention in stochastic simulations, where random numbers should actually be semi-random numbers. An exception to reproducibility are “human-in-the-loop” simulations, such as flight simulations and computer games. Here a human is part of the simulation and thus influences the outcome in a way that is hard if not impossible to reproduce exactly. Computer graphics can be used to display the results of a computer simulation. Animations can be used to experience a simulation in real-time e.g. in training simulations. In some cases animations may also be useful in faster than real-time or even slower than real-time modes. For example, faster than real-time animations can be useful in visualizing the build-up of queues in the simulation of humans evacuating a building. Furthermore, simulation results are often aggregated into static images using various ways of scientific visualization. In debugging, simulating a program execution under test (rather than executing natively) can detect far more errors than the hardware itself can detect and, at the same time, log useful debugging information such as instruction trace, memory alterations and instruction counts. This technique can also detect buffer overflow and similar “hard to detect” errors as well as produce performance information and tuning data.

**Computer simulation in science**

The following are generic examples of types of computer simulations in science, which are derived from an underlying mathematical description: A numerical simulation of differential equations which cannot be solved analytically. Falling into this category are:

• fluid dynamics (e.g. climate models, roadway noise models, roadway air dispersion models)

• computational fluid dynamics simulations are used to simulate the behaviour of flowing air, water and other fluids. There are one-, two- and three- dimensional models used. A one dimensional model might simulate the effects of water hammer in a pipe. A two-dimensional model might be used to simulate the drag forces on the cross-section of an aeroplane wing. A three-dimensional simulation might estimate the heating and cooling requirements of a large building.

• continuum mechanics and chemical kinetics

• statistical simulations based upon an agglomeration of a large number of input profiles, such as the forecasting of equilibrium temperature of receiving waters, allowing the gamut of meteorological data to be input for a specific locale. This technique was developed for thermal pollution forecasting.

• agent based simulation has been used effectively in ecology, where it is often called individual based modelling and has been used in situations for which individual variability in the agents cannot be neglected, such as population dynamics of salmon and trout (most purely mathematical models assume all trout behave identically)

• time stepped dynamic model; in hydrology there are several such hydrology transport models such as the SWMM and DSSAM Models developed by the U.S. Environmental Protection Agency for river water quality forecasting

• computer simulation using molecular modelling for drug discovery

• computer simulations have also been used to formally model theories of human cognition and performance, e.g. ACT-R