**Computer simulation**

A computer simulation (or "sim") is an attempt to model a real-life or hypothetical situation on a computer so that it can be studied to see how the system works. By changing variables in the simulation, [predictions](https://en.wikipedia.org/wiki/Prediction) may be made about the behaviour of the system. It is a tool to virtually investigate the behaviour of the system under study.

Computer simulation has become a useful part of [modeling](https://en.wikipedia.org/wiki/Model_%28abstract%29) many natural systems in [physics](https://en.wikipedia.org/wiki/Physics), [chemistry](https://en.wikipedia.org/wiki/Chemistry) and [biology](https://en.wikipedia.org/wiki/Biology), and human systems in [economics](https://en.wikipedia.org/wiki/Economics) and [social science](https://en.wikipedia.org/wiki/Social_science) (e.g., [computational sociology](https://en.wikipedia.org/wiki/Computational_sociology)) as well as in [engineering](https://en.wikipedia.org/wiki/Engineering) to gain insight into the operation of those systems. A good example of the usefulness of using computers to simulate can be found in the field of [network traffic simulation](https://en.wikipedia.org/wiki/Network_traffic_simulation). In such simulations, the [model](https://en.wikipedia.org/wiki/Model_%28abstract%29) behaviour will change each simulation according to the set of initial parameters assumed for the environment.

Traditionally, the formal modeling of systems has been via a [mathematical model](https://en.wikipedia.org/wiki/Mathematical_model), which attempts to find analytical solutions enabling the prediction of the behaviour of the system from a set of parameters and initial conditions. Computer simulation is often used as an adjunct to, or substitution for, modeling systems for which simple [closed form analytic solutions](https://en.wikipedia.org/wiki/Closed-form_solution) 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](https://en.wikipedia.org/wiki/Scenario) for a model in which a complete enumeration of all possible states would be prohibitive or impossible.

Several software packages exist for running computer-based simulation modeling (e.g. [Monte Carlo](https://en.wikipedia.org/wiki/Monte_Carlo_method) simulation, [stochastic modeling](https://en.wikipedia.org/wiki/Stochastic), multimethod modeling) that makes all the modeling almost effortless.

Modern usage of the term "computer simulation" may encompass virtually any computer-based representation.

**Computer science**

In [computer science](https://en.wikipedia.org/wiki/Computer_science), simulation has some specialized meanings: [Alan Turing](https://en.wikipedia.org/wiki/Alan_Turing) used the term "simulation" to refer to what happens when a [universal machine](https://en.wikipedia.org/wiki/Universal_Turing_machine) executes a state transition table (in modern terminology, a computer runs a program) that describes the state transitions, inputs and outputs of a subject discrete-state machine. The computer simulates the subject machine. Accordingly, in [theoretical computer science](https://en.wikipedia.org/wiki/Theoretical_computer_science) the term [*simulation*](https://en.wikipedia.org/wiki/Simulation_preorder) is a relation between [state transition systems](https://en.wikipedia.org/wiki/State_transition_system), useful in the study of [operational semantics](https://en.wikipedia.org/wiki/Operational_semantics).

Less theoretically, an interesting application of computer simulation is to simulate computers using computers. In [computer architecture](https://en.wikipedia.org/wiki/Computer_architecture), a type of simulator, typically called an [*emulator*](https://en.wikipedia.org/wiki/Emulator), is often used to execute a program that has to run on some inconvenient type of computer (for example, a newly designed computer that has not yet been built or an obsolete computer that is no longer available), or in a tightly controlled testing environment (see [*Computer architecture simulator*](https://en.wikipedia.org/wiki/Computer_architecture_simulator) and [*Platform virtualization*](https://en.wikipedia.org/wiki/Platform_virtualization)). For example, simulators have been used to debug a [microprogram](https://en.wikipedia.org/wiki/Microprogram%22%20%5Co%20%22Microprogram) or sometimes commercial application programs, before the program is downloaded to the target machine. Since the operation of the computer is simulated, all of the information about the computer's operation is directly available to the programmer, and the speed and execution of the simulation can be varied at will.

Simulators may also be used to interpret [fault trees](https://en.wikipedia.org/wiki/Fault_tree), or test [VLSI](https://en.wikipedia.org/wiki/VLSI) logic designs before they are constructed. [Symbolic simulation](https://en.wikipedia.org/wiki/Symbolic_simulation) uses variables to stand for unknown values.

In the field of [optimization](https://en.wikipedia.org/wiki/Optimization_%28mathematics%29), simulations of physical processes are often used in conjunction with [evolutionary computation](https://en.wikipedia.org/wiki/Evolutionary_computation) to optimize control strategies.

Simulation in education and training

Simulation is extensively used for educational purposes. It is used for cases where it is prohibitively expensive or simply too dangerous to allow trainees to use the real equipment in the real world. In such situations they will spend time learning valuable lessons in a "safe" virtual environment yet living a [lifelike experience](https://en.wikipedia.org/wiki/Lifelike_experience) (or at least it is the goal). Often the convenience is to permit mistakes during training for a safety-critical system.

Simulations in education are somewhat like training simulations. They focus on specific tasks. The term 'microworld' is used to refer to educational simulations which model some abstract concept rather than simulating a realistic object or environment, or in some cases model a real-world environment in a simplistic way so as to help a learner develop an understanding of the key concepts. Normally, a user can create some sort of construction within the microworld that will behave in a way consistent with the concepts being modeled. [Seymour Papert](https://en.wikipedia.org/wiki/Seymour_Papert) was one of the first to advocate the value of microworlds, and the [Logo](https://en.wikipedia.org/wiki/Logo_%28programming_language%29) programming environment developed by Papert is one of the most well-known microworlds.

[Project Management Simulation](https://en.wikipedia.org/wiki/Project_Management_Simulation) is increasingly used to train students and professionals in the art and science of project management. Using simulation for [project management](https://en.wikipedia.org/wiki/Project_management) training improves learning retention and enhances the learning process.

*Social simulations* may be used in social science classrooms to illustrate social and political processes in anthropology, economics, history, political science, or sociology courses, typically at the high school or university level. These may, for example, take the form of civics simulations, in which participants assume roles in a simulated society, or international relations simulations in which participants engage in negotiations, alliance formation, trade, diplomacy, and the use of force. Such simulations might be based on fictitious political systems, or be based on current or historical events. An example of the latter would be [Barnard College](https://en.wikipedia.org/wiki/Barnard_College)'s *Reacting to the Past* series of historical educational games. The [National Science Foundation](https://en.wikipedia.org/wiki/National_Science_Foundation) has also supported the creation of [reacting games](https://en.wikipedia.org/wiki/Reacting_games) that address science and math education. In social media simulations, participants train communication with critics and other stakeholders in a private environment.

In recent years, there has been increasing use of social simulations for staff training in aid and development agencies. The Carana simulation, for example, was first developed by the [United Nations Development Programme](https://en.wikipedia.org/wiki/United_Nations_Development_Programme), and is now used in a very revised form by the [World Bank](https://en.wikipedia.org/wiki/World_Bank) for training staff to deal with fragile and conflict-affected countries.

Military uses for simulation often involve aircraft or armoured fighting vehicles, but can also target small arms and other weapon systems training. Specifically, virtual firearms ranges have become the norm in most military training processes and there is a significant amount of data to suggest this is a useful tool for armed professionals.

Common user interaction systems for virtual simulations

Virtual simulations represent a specific category of simulation that utilizes simulation equipment to create a simulated world for the user. Virtual simulations allow users to interact with a virtual world. Virtual worlds operate on platforms of integrated software and hardware components. In this manner, the system can accept input from the user (e.g., body tracking, voice/sound recognition, physical controllers) and produce output to the user (e.g., visual display, aural display, haptic display). Virtual Simulations use the aforementioned modes of interaction to produce a sense of [immersion](https://en.wikipedia.org/wiki/Immersion_%28virtual_reality%29) for the user.

**Virtual simulation input hardware**

There is a wide variety of input hardware available to accept user input for virtual simulations. The following list briefly describes several of them:

**Body tracking**: The [motion capture](https://en.wikipedia.org/wiki/Motion_capture) method is often used to record the user's movements and translate the captured data into inputs for the virtual simulation. For example, if a user physically turns their head, the motion would be captured by the simulation hardware in some way and translated to a corresponding shift in view within the simulation.

* [Capture suits](https://en.wikipedia.org/wiki/Mo-cap_suit) and/or gloves may be used to capture movements of users body parts. The systems may have sensors incorporated inside them to sense movements of different body parts (e.g., fingers). Alternatively, these systems may have exterior tracking devices or marks that can be detected by external ultrasound, optical receivers or electromagnetic sensors. Internal inertial sensors are also available on some systems. The units may transmit data either wirelessly or through cables.
* [Eye trackers](https://en.wikipedia.org/wiki/Eye_tracker) can also be used to detect eye movements so that the system can determine precisely where a user is looking at any given instant.

**Physical controllers**: Physical controllers provide input to the simulation only through direct manipulation by the user. In virtual simulations, tactile feedback from physical controllers is highly desirable in a number of simulation environments.

* [Omnidirectional treadmills](https://en.wikipedia.org/wiki/Omnidirectional_treadmill) can be used to capture the users locomotion as they walk or run.
* High fidelity instrumentation such as instrument panels in virtual aircraft cockpits provides users with actual controls to raise the level of immersion. For example, pilots can use the actual [global positioning system](https://en.wikipedia.org/wiki/Global_positioning_system) controls from the real device in a simulated cockpit to help them practice procedures with the actual device in the context of the integrated cockpit system.

**Voice/sound recognition**: This form of interaction may be used either to interact with agents within the simulation (e.g., virtual people) or to manipulate objects in the simulation (e.g., information). Voice interaction presumably increases the level of immersion for the user.

* Users may use headsets with boom microphones, lapel microphones or the room may be equipped with strategically located microphones.

**Current research into user input systems**[[edit](https://en.wikipedia.org/w/index.php?title=Simulation&action=edit&section=7" \o "Edit section: Current research into user input systems)]

Research in future input systems holds a great deal of promise for virtual simulations. Systems such as [brain–computer interfaces](https://en.wikipedia.org/wiki/Brain%E2%80%93computer_interface) (BCIs) offer the ability to further increase the level of immersion for virtual simulation users. Lee, Keinrath, Scherer, Bischof, Pfurtscheller[[26]](https://en.wikipedia.org/wiki/Simulation%22%20%5Cl%20%22cite_note-26) proved that naïve subjects could be trained to use a BCI to navigate a virtual apartment with relative ease. Using the BCI, the authors found that subjects were able to freely navigate the virtual environment with relatively minimal effort. It is possible that these types of systems will become standard input modalities in future virtual simulation systems.

**Virtual simulation output hardware**

There is a wide variety of output hardware available to deliver a stimulus to users in virtual simulations. The following list briefly describes several of them:

**Visual display**: Visual displays provide the visual stimulus to the user.

* Stationary displays can vary from a conventional desktop display to 360-degree wrap-around screens to stereo three-dimensional screens. Conventional desktop displays can vary in size from 15 to 60 inches (380 to 1,520 mm). Wrap around screens is typically utilized in what is known as a [cave automatic virtual environment](https://en.wikipedia.org/wiki/Cave_automatic_virtual_environment) (CAVE). Stereo three-dimensional screens produce three-dimensional images either with or without special glasses—depending on the design.
* [Head-mounted displays](https://en.wikipedia.org/wiki/Head-mounted_display) (HMDs) have small displays that are mounted on headgear worn by the user. These systems are connected directly into the virtual simulation to provide the user with a more immersive experience. Weight, update rates and field of view are some of the key variables that differentiate HMDs. Naturally, heavier HMDs are undesirable as they cause fatigue over time. If the update rate is too slow, the system is unable to update the displays fast enough to correspond with a quick head turn by the user. Slower update rates tend to cause simulation sickness and disrupt the sense of immersion. Field of view or the angular extent of the world that is seen at a given moment [field of view](https://en.wikipedia.org/wiki/Field_of_view) can vary from system to system and has been found to affect the user's sense of immersion.

**Aural display**: Several different types of audio systems exist to help the user hear and localize sounds spatially. Special software can be used to produce 3D audio effects [3D audio](https://en.wikipedia.org/wiki/3D_audio) to create the illusion that sound sources are placed within a defined three-dimensional space around the user.

* Stationary conventional speaker systems may be used to provide dual or multi-channel surround sound. However, external speakers are not as effective as headphones in producing 3D audio effects.
* Conventional headphones offer a portable alternative to stationary speakers. They also have the added advantages of masking real-world noise and facilitate more effective 3D audio sound effects.

**Haptic display**: These displays provide a sense of touch to the user ([haptic technology](https://en.wikipedia.org/wiki/Haptic_technology%22%20%5Co%20%22Haptic%20technology)). This type of output is sometimes referred to as force feedback.

* Tactile tile displays use different types of actuators such as inflatable bladders, vibrators, low-frequency sub-woofers, pin actuators and/or thermo-actuators to produce sensations for the user.
* End effector displays can respond to users inputs with resistance and force. These systems are often used in medical applications for remote surgeries that employ robotic instruments.

**Vestibular display**: These displays provide a sense of motion to the user ([motion simulator](https://en.wikipedia.org/wiki/Motion_simulator)). They often manifest as motion bases for virtual vehicle simulation such as driving simulators or flight simulators. Motion bases are fixed in place but use actuators to move the simulator in ways that can produce the sensations pitching, yawing or rolling. The simulators can also move in such a way as to produce a sense of acceleration on all axes (e.g., the motion base can produce the sensation of falling).