CS50 Models and Simulations

Overview

Computers are powerful because they can make complex calculations very quickly. One of the ways we can take advantage of this power is by creating models and simulations to represent complex objects and/or events. By creating virtual representations of things we are curious about, we can increase safety, save money and time, stretch our imaginations, and ultimately learn more about the world around us.

Key Terms

- model
- simulation

Building Models and Simulations

A **model** is a static representation of an object or a system. On a computer, models are often made up of algorithms, equations, and/or visual reconstructions. A **simulation** is a dynamic representation of a model, or the running of a model. Simulations allow us to change variables of a model and observe the effects of those variable changes. Where models seek to replicate features of an object or a system, simulations seek to replicate behaviors.

Models and simulations are implemented on a computer by creating a set of parameters that define the represented system. For example, to create a simulation of a bouncing ball, you would program the mass of the ball, the force of gravity, the springiness of the ball, and the type of collision, all as mathematical equations. The computer would then be able to mimic the way a ball bounces in reality, providing an isolated and controlled reality for scientists to play with. However, more often than not, models and simulations don't attempt to represent all factors of a system. Instead, they focus on the relevant ones. Relevant factors can include factors of interest for a particular research project, or factors that have the most significant effects on a system. Models and simulations are often designed to be simplified versions of a real object or phenomena, making them easier for us to analyze and understand. Ultimately, because we input parameters of models and simulations, we have full control of what we'd like to get out of them.

Applications and Limitations

Because models and simulations essentially create virtual copies of our world, they are used in nearly every field today. Models and simulations allow people to engage in test runs without going through the real thing, providing low-risk training for less time and money. For example, simulations are used by the military to train soldiers for dangerous situations and by medical schools to train doctors for various medical procedures. Simulations can also be used in therapy for those with mental health issues. Beyond training, models and simulations can be used to learn more about a system or phenomena. Meteorologists use simulations to predict upcoming weather, economists use models to analyze markets and make predictions, and ecologists use models to better understand living systems. Even things like traffic can be modeled using simulations, helping us develop better solutions to practical problems. Models and simulations can be as large or small scale as we want. We can use simulations to analyze anything from molecular interactions to the Big Bang; the scale and detail of a model is a part of its design. Outside of research and analysis, models and simulations can be used for entertainment. Models and simulations are used in movies and video games to create computer-generated imagery (CGI), enabling us to construct realistic yet fantastical worlds and beautiful animation.

However, models and simulations are not the perfect solution to everything. While they clearly have many potential benefits, it is important to remember that models and simulations are abstractions of reality and may not be entirely accurate. Models must be calibrated, verified, and validated before they can be considered accurate, and even then, there is potential for error. In addition, there are significant costs for models and simulations. They require a significant investment to create, and depending on the complexity of the model or simulation, they may require a lot of computational power, therefore costing a lot of money. Nevertheless, computer models and simulations have been an invaluable tool in nearly all disciplines. As computers continue to become more powerful, models and simulations will too.