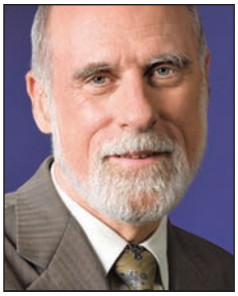
On the Simulation of Everything



Vinton G. Cerf • *Google*

I recently visited Singapore, where I met with a team from the Eidgenössiche Technische Hochschule (ETH) Zurich in Switzerland. The team is working on a detailed simulation of the entire city-state of Singapore, down to individual models of stereotypic residents. This work is being undertaken in the Campus for Research Excellence and Technological Enterprise (CREATE; http://utown.nus.edu.sg/about-university-town/create-2) in University Town, developed specifically for this kind of innovative work. Within that facility is the Singapore-ETH Centre where the modeling work (among many other projects) takes place. Other institutions are cooperating within the CREATE framework, but in this article, I want to focus specifically on this simulation work.

The idea is to model in detail all aspects of the city's operation from the standpoint of its facilities: transportation, traffic flow of all kinds (including foot traffic and public transport, as well as personal cars and delivery vehicles), energy and water usage, buildings and their resource demands, waste disposal, and many other measurable aspects of city operation. That such simulations are feasible is a consequence of the computing and memory capacity now available at a reasonable cost. Understanding the resource needs of the entire city leads to the ability to ask "what if" questions for city planning, emergency response, and adjusting various policies to level peak demands or other situational considerations.

More recently, I attended a Google event called Google Cloud Next 2017 and met the CEO of a new company, Improbable (https://improbable.io/company/about-us). This company is attempting the same kind of effort, not only for detailed simulation of cities, but more generally the simulation of everything. There are scaling and visualization challenges that go along with such efforts that make them particularly interesting as computational exercises. Among the challenges is almost certainly the level of detail of each aspect of the simulation. You can readily imagine a multilevel simulation in which some parts are accomplished with summary computations that model some aspects in high-level equations, while others are modeled in great detail. Figuring out how to move the right information between levels of abstractions without distorting the results so much as to make the simulation invalid is one of the key problems to solve. This isn't a new problem, but it's important to be able to run such simulations in reasonable time frames if not in real time.

On the visualization front, the works in Singapore and at Improbable offer notable opportunities to allow researchers to examine the city's behavior from multiple points of view and at many levels of abstraction. You might want to see aggregate statistics about city traffic, resource usage, and other important parameters; or you might want to "zoom in" to observe traffic flow at the level of individual vehicles or even foot traffic. You could imagine instrumenting the city with the intent of gathering data to validate the simulation models, leading to one useful implementation of a "smart city." Indeed, the simulation might well be used for feedback to such an instrumented city — information that would allow for adjusting various operational parameters to reduce congestion, energy usage, and other vital aspects of city functions.

This evokes thoughts about the popular SIM games (https://en.wikipedia.org/wiki/List_of_Sim_video_games) that cover a remarkable range of simulations, from individual lives to civilizations. These kinds of simulations have the interesting property that you can experiment with different policies and learn from their effects. Even if the simulation results might be speculative, they can create a deeper appreciation

1089-7801/17/$33.00 © 2017 IEEE
Published by the IEEE Computer Society

for the interconnectedness of processes, including artificial ones. After all, what's a city if not a highly connected artifact of human-created processes and constructs?

This notion of artifact has drawn me once again to read for the *n*th time Herbert Simon's *Sciences of the Artificial*,[1] which is in its third edition. This magnificent book dives deeply into design — and here lies the heart of the value of the simulations we've been discussing. We design artifacts of increasing complexity and out of those designs emerge phenomena we might not have predicted. Emergent behavior isn't a new idea, but it's relevant to the utility of accurate simulations of complex phenomena. Indeed, complexity isn't required to encounter unexpected behaviors. John Conway's famous Life game (https://en.wikipedia.org/wiki/Conway's_Game_of_Life) exhibits a variety of unexpected phenomena, including replicable flyers and "Garden of Eden" configurations. There are deep insights to be had from high-resolution simulations. The best is yet to come.

Reference

1. H. Simon, *Sciences of the Artificial*, 3rd ed., MIT Press, 1978; https://mitpress.mit.edu/books/sciences-artificial.

Vinton G. Cerf is vice president and chief Internet evangelist at Google, and past president of ACM. He's widely known as one of the "fathers of the Internet." He's a Fellow of IEEE and ACM. Contact him at vgcerf@gmail.com.