Predicting the Probability of Congestion

KARL SIGMAN

Professor of Industrial Engineering and Operations Research

When people refer to the World Wide Web as an information superhighway, they rarely consider traffic jams. Yet congestion slows the movement of information around the web, and appears naturally in systems as diverse as highways and hospitals.

Karl Sigman uses probability tools to build and analyze mathematical models of congestion, also known as queueing. A simple example is an ATM machine, where people arrive randomly and sometimes find themselves waiting in line to use the machine.

Successfully analyzing queueing models can help optimally route requests to a set of web servers, staff a call center, process jobs in a manufacturing plant, and schedule surgeries in a hospital.

The mathematics of probability gives Sigman many insights into a model's evolution. Still, many models remain breathtakingly complex due to the inherent randomness involved in the real world.

"Randomness, such as when the next request arrives or when something breaks, affects all these systems," said Sigman. "The further you look into the future, the more random it can become. It's like stock prices. Tomorrow's price is likely to be similar to today's, but the price next week is less certain.

"I'm interested in the relationship between what system users see and what the system actually does," he explained. "A user might click a link on a website. How long he or she waits to see the page is a measure of congestion from the user's perspective."

A system observer's viewpoint is different. "He or she looks at the web server over time and asks, 'How many users are trying to access a given page?' It does not look at the experience of any given user," Sigman said.

"This is also a measure of congestion and system performance, but from different perspectives," Sigman added. Yet the two views are interrelated. In fact, the solution to a problem from one perspective can sometimes be transformed into the desired solution from the other perspective.

Sigman has spent years teasing out those connections. "Sometimes the model looks very complicated from the perspective of a user, but it proves easier to solve from the perspective of an observer," he said.

Sigman joined Columbia Engineering in 1987. He was the recipient of the Distinguished Faculty Teaching Award both in 1998 and in 2002. He teaches courses in stochastic models, financial engineering, and queueing theory. Before joining Columbia, Sigman was a postdoctoral associate at the Mathematical Sciences Institute at Cornell University.

B.A., University of California-Santa Cruz, 1980; M.A., University of California-Berkeley, 1983; M.S., UC Berkeley, 1984; Ph.D., UC Berkeley, 1986