Carlo

From Super Bowls to hurricanes, this simulation method helps predict them all

Monte Carlo simulations helped give emergency workers advance warning that Hurricane Sandy would make landfall in New Jersey and New York. Here, an Oct. 31, 2012 file photo of homes in Ortley Beach, N.J. destroyed by the storm. **PHOTO:** MIKE GROLL/ASSOCIATED PRESS

By Jo Craven McGinty

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When Hurricane Sandy began swirling off the coast of Florida in 2012, the earliest forecasts suggested the gigantic storm was unlikely to hit land.

If it wasn't headed for the coast, everyone could relax. But if landfall was imminent, emergency workers would want as much time as possible to prepare.

Sandy, as we know, pummeled the Eastern Seaboard—especially New York and New Jersey—with damage reaching west all the way to Wisconsin. But thanks to computerized probability simulations, like the ones used for some financial forecasts, meteorologists tracking the storm weren't caught off guard.

"We probably knew about 72 hours ahead," said Altug Aksoy, a scientist at the Atlantic Oceanographic and Meteorological Laboratory, noting that European models detected the storm's true path about a day ahead of U.S.

models. On average, European models perform better in part because they run more simulations with more data points on more powerful computers.

Today, storm trackers don't rely on a single forecast, or even a handful of predictions. Instead, they plot numerous potential scenarios and review all of the results to determine the probability a storm will take one path versus another or predict how intense it's likely to be.

The approach is called ensemble forecasting, and it's a kind of Monte Carlo simulation.

The concept was inspired by a game of solitaire when mathematician Stanislaw Ulam, a key figure in the Manhattan Project, wondered about his chances of laying out a winning round. Unable to come up with a mathematical solution to the problem, he hit upon the idea of having a computer simulate games to arrive at the answer. He named the approach—which helped guide the development of the atomic bomb—after the famous casino in Monaco.

There are different kinds of Monte Carlo simulations, but in general, the computerized models involve randomly selecting data points for a given situation from a range of possible numbers and calculating the outcome.

As with polling, a randomly chosen sample tends to exhibit the same properties as the population from which it is drawn.

But instead of running a single simulation, the computer will repeat the process many times with different randomly chosen variables. Using a range of possible values provides a better idea of what might happen in the future, and depending on the simulation, it could run through dozens, hundreds, thousands or millions of scenarios.

Monte Carlo simulations are a way of addressing any number of complex problems that can't be easily solved with an equation. In Ulam's solitaire example, a computer would simply play game after game, compiling the results, until the chance of dealing a winning hand becomes apparent.

"You can brute-force it with Monte Carlo," said Art B. Owen, a statistics professor at Stanford University who researches Monte Carlo methods. "The problem is too complicated to solve with an algebraic formula. So you repeat random outcomes millions of times and look at what happens."

The Environmental Protection agency uses Monte Carlo simulations to estimate the likely severity of adverse health effects from exposure to hazardous material.

The Maryland Transportation Department has used the simulations to estimate how long it will take freeway traffic to return to normal after an accident, information the department uses to figure out whether it detects and clears accidents in a cost-effective manner.

Pharmaceutical companies use the simulations to help guide the expensive task of researching and developing of new drugs.

Monte Carlo simulations have also been used to predict the outcome of the

Super Bowl and to forecast elections.

"Every business plan has some sort of target," said Sam Savage, author of "The Flaw of Averages" and executive director of Probability Management, a nonprofit that promotes using probability distributions to make business decisions and provides free tools. "A restaurant could do it to model how much fish to buy for tomorrow's menu given the uncertainty for the demand for fish."

The simulations do have limits. The randomly sampled variables might be based on historical data or expert assumptions. It's possible past behavior may not be a good predictor of future behavior, and expert assumptions may be flawed.

"The result is not valid if the underlying data used to run the simulation is wrong," said John Guttag, a professor of Electrical Engineering and Computer Science at MIT who has lectured on Monte Carlo simulation. "There is no magic to beat garbage in, garbage out."

In the case of Hurricane Sandy, meteorologists ran 50 different scenarios with more than 10 million randomized atmospheric variables at six-hour intervals as the storm progressed, with each scenario redefining the temperature, wind, moisture, air pressure and other variables.

"When Sandy was just crossing Cuba, a lot of the forecasts were pointing out to the Atlantic," Dr. Aksoy said. "No landfall. But some started pointing towards land. That's when we started thinking there is a slight chance a different scenario might occur."

As with any forecasting tool, the results of a Monte Carlo simulation can't guarantee the future. But viewing myriad potential outcomes through the lens of probability statistics can help lift the cloud of uncertainty.

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