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Mathematical supermodels refine epidemic predictions

Research at Reed College shows promise in giving detailed forecasts about how diseases spread

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Before the fire, Richard Crandall's computerized wilderness looks like a flag: one small red dot on a field of green.

A quick click sets this silicon forest ablaze. The ring of fire spreads, leaving a ragged-edged red circle spattered with tiny green flecks.

The green "survivors" seem randomly scattered through the dead zone. But complex calculations by Crandall and his Reed College students show that the survivors form a "fractal set," a nonrandom pattern in which subtle repetitions offer information about the crisis that created them.

With some tweaks, that crisis can be a disease instead of a flame. The Reed group has already loosed smallpox through Conflagrator -- their name for the computer program that graphically plays out their disaster model.

The smallpox also spreads in a fractal pattern, a fact that could help medics plan for outbreaks and suggests a new strategy for using limited vaccine supplies, Crandall said.

The model is "a new tool that makes sharper predictions for some phenomena, such as sudden surges in an epidemic (or) vaccination strategies when you cannot vaccinate everyone," he said.

Conflagrator represents a new way of thinking, fundamentally different than traditional disease models, that could influence public health efforts in Portland and perhaps the nation or world.

An unusual collaboration produced this model. The main research arm of the U.S. Department of Defense gave two grants to explore how disease spreads. The investigators are Crandall and Reed biology professor Stephen Arch. Reed undergraduates studying biology, math and physics feed into the research, Crandall said.

"What they said they want is young people, college students, to start learning about bioterror issues," he said.

The cutting-edge science springs from an old wood bungalow in an overgrown corner of Reed. The house holds the Center for Advanced Computation, directed by Crandall, a computational physicist who salts his conversation with casual references to space-time and quantum tunnels. In the basement, several computers link with others across Reed to form a powerful supercomputer.

That system is now working to prove the math underlying the new disease model with what Crandall calls "deep computation." That means the project involves a billion billion computer operations -- the same number that yielded the animated movie Finding Nemo, Crandall says.

The project takes roughly 30 machines about six months to finish, Crandall estimates, and should be done by fall. He hopes to publish the results and release a computer program to help emergency planners model crises such as disease outbreaks.

Such models are useful tools, especially for new or rare diseases, such as SARS or smallpox.

"We can't say, 'Oh, let's see what happens when we give these people smallpox,' " said Amy Sullivan, a Multnomah County Health Department epidemiologist who has worked with Crandall. Making models "gives you a way of constructing a system and seeing how it might act."

Most modern disease models were developed about 100 years ago, she said, in response to malaria epidemics. They use statistics and a series of equations to define in general terms how epidemics progress. In graphic form, Crandall said, the models draw smooth, continuous curves.

The Reed model is notably different. Technically speaking, it relies on parametric relationships and fractals, not differential equations and curves, Crandall said. Simply put, the new model is "discrete," not "continuous." It considers millions of interactions event by event -- as represented by each tiny green speck in the virtual forest fire.

The difference is notable in disease outbreaks. Traditional models "would say everyone in the state of Iowa has the same risk" for disease, Crandall said. The Reed model calculates case by case, considering such parameters as how people interact socially and who may have immunity.

For SARS, which emerged in Asia last year, old models would assume every sick person would affect, say, 1.9 other people, Sullivan said. But the 2003 outbreak showed much more variation, with some sick people spreading the disease to no one and a few "superspreaders" infecting more than a dozen others. The Reed model can mimic that behavior, as well as other characteristics of some diseases, such as a tendency to spread in waves rather than at a steady rate.

The model also can show where an epidemic is poised to spread faster, helping direct a response, Crandall said.

When mapping a smallpox epidemic, the model shows more infections "percolating" where the map's edges get more crinkly-looking -- more fractal in nature, Crandall said. In other words, 10 initial disease cases spread out geographically could create a more severe epidemic than 10 which stay clustered in a small area.

That knowledge suggests that limited vaccines should be targeted toward the percolating spots, what Crandall described as a hot spot vaccine strategy.

"If the CDC has a map of the middle of Kansas that looks like a starfish, and a map of the middle of Kentucky that looks like a circle, go for the starfish," he said.

That strategy differs from the government's standing "ring vaccination" plan for smallpox -- inoculating everyone who comes in contact with a known case -- an idea that other epidemic experts have started to question.

Crandall said such ideas are an effort to suggest "scientific policy" -- a science-based idea which might differ from social or government policies. Sullivan said that the new model could join other tools health officials use to plan for epidemics, not replace them. Just because the new model suggests a course of action, she adds, "doesn't mean we'd do it" without other support.

But Sullivan said the county may use the new model to help plan, not only for disease threats but also existing problems such as pertussis, or whooping cough.

"It's really exciting, actually, for somebody who's involved in the planning side," she said. "It's really going to let us use some cutting-edge approaches to our public health strategy."

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