Medical Xpress

Shining a stochastic spotlight on Ebola

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The 2014 outbreak of Ebola virus disease, the worst since the disease first appeared in 1976, has claimed more than 11,000 lives in the West African nations of Guinea, Sierra Leone and Liberia, and a handful more in nearby Nigeria and Mali.

The disease, which kills as many as 70 percent of the people it infects, continues to be active in Guinea and Sierra Leone. Elsewhere the outbreak has ended.

Although Ebola has concentrated its deadliest effects in West Africa, scientists believe the virus originated in the Democratic Republic of Congo, nearly 3,000 miles away, and that it is carried—and transmitted to humans—by bats.

Such a scenario, says Javier Buceta, an associate professor of chemical and biomolecular engineering, raises a number of questions.

What aspects of their behavior determine whether and how bats become infected? How do bats infect humans? How does the virus travel such a distance?

And, perhaps most importantly, what steps can humans take to prevent an outbreak or halt its spread?

Because these questions involve so many random variables and because the spread of Ebola is difficult if not impossible to predict, Buceta is seeking to develop computational models that measure the probability that a particular result or results will occur.

Buceta and Paolo Bocchini, an assistant professor of civil and environmental engineering, were recently awarded a one-year Collaborative Research (CORE) Grant (http://research.cc.lehigh.edu/collaborative-research-opportunity-core-grants) from the provost's office to apply stochastic modeling to the spread of Ebola.

Their goal is twofold: to use their model in the short term to develop more effective methods of predicting, mapping and responding to disease outbreaks and natural disasters, and to expand their collaboration in the long term to include social scientists and economists.

The project is titled "Functional Quantization of Ebola Zoonotic Spreading: A Kernel for the Establishment of a Research Thrust on Stochastic Computation and Random Functions (SCaRF) at Lehigh."

A dynamic and random set of variables

Buceta has spent years developing mathematical models of the spread of the Hantavirus, which is carried by the deer mouse and can cause potentially fatal diseases in humans.

"When I first started reading about Ebola," he says, "I realized there weren't many models of the bats that carry the virus. I came up with the idea of developing stochastic models to study the dynamics of the infection of the bat population.

"Many factors affect these dynamics, including environment, climate, migratory habits and availability of resources. If bats have to fight for food, this increases the chances they will infect each other. Another factor is seasonality and the fact that bat babies may be the main carriers.

"To understand the systemic behavior of the bat population, you have to sample all of these variables."

Bocchini develops stochastic models to analyze the effects of an earthquake, hurricane or other natural disaster on an infrastructure network, say, on all the bridges in the Lehigh Valley. The models help engineers anticipate how much damage will occur and where, the possible effects on traffic patterns, and which bridges will most likely need to be shut down.

"When I started talking with Javier about random functions," says Bocchini, "I realized that some of the mathematical tools I use to describe natural disasters could be applied to the sampling of the spread of the Ebola virus.

"The tool Javier has been developing is descriptive; he's trying to predict how a virus will spread. My goal is to develop probabilistic methods to support decisions such as the allocation of resources. I try to make a model computationally feasible to use in the real world."

A rigorous effort to quantify risk

By joining forces, the researchers hope to combine Buceta's random diffusion model with the advances in random field sampling that Bocchini and his group have achieved.

"This synergy," they say, "will allow us to...rigorously quantify the risk associated with the spread of a virus over a large geographical area [and] to perform probabilistic cost-benefit analyses and concentrate resources to fight an epidemic in the areas where they will be most effective."

In 1902, the researchers note, the British physician Ronald A. Ross won the Nobel Prize for Medicine for using mathematical modeling to link mosquitoes to malaria outbreaks. But no model has yet been developed that can forecast the outbreak and spread of Ebola while taking into account the geographical size of the area under consideration and the randomness of the variables involved.

"For such a model to be useful in terms of its predictive capabilities," the researchers say, "we must be able to quantify the effective probability that an outbreak will develop at particular locations. This requires adequately sampling a very large space."

This sampling will be done using a methodology called functional quantization (FQ), which was developed to study fluctuations in the stock market. FQ is ideally suited to problems that are too complex to be analyzed using traditional computational methods, the researchers say.

"FQ provides an optimal representation of an entire stochastic space using a small number of samples that are carefully selected and weighted to truly capture all possible configurations. It will make it possible to obtain 'hazard maps' that show the probability of Ebola reaching a community for a given set of initial conditions.

"This type of constantly evolving information will allow authorities to react promptly to the diffusion of the disease and concentrate available resources where they can be most effective."

In the future, Buceta and Bocchini hope to collaborate with political scientists, social scientists, economists and policy makers who work in the area of disaster preparedness and response. One logical area of joint inquiry, says Bocchini, is the interaction of natural disasters and viral outbreaks and its effect on economic recovery.

"It would be very useful to partner with people from these other disciplines," says Bocchini. "A large number of them work in this area, but very few approach the topic from a quantitative viewpoint.

"We hope this CORE project will be the first step in a larger collaboration."

Provided by Lehigh University