Modeling through Challenge

Chikungunya Fever in the Americas

Joceline Lega

Photo by David Dean Rodrigo T.-R. McLaughlin

In August 2014, DARPA (the federal Defense Advanced Research Projects Agency) launched a challenge, asking the public to predict the number of cases of chikungunya fever in each of the PAHO (Pan American Health Organization) countries, many of which were for the first time facing a huge outbreak of this disease. The framework was simple: predictions would be compared to numbers of reported cases, and teams would be scored on the accuracy of their approach. When a colleague in the College of Public Health, Dr. Heidi Brown, forwarded the announcement to me, I found the format both appealing and intriguing. First, this provided a unique opportunity (at least for a mathematician) to observe the unfolding of an epidemic in an area where it had never been reported before. Second, the funding approach was different.

Grants versus challenges

Academic research is typically supported by grants or contracts: funds are allocated based on proposals, which are evaluated for their intellectual merit. About 6 years ago, "President Obama called on [federal] agencies to increase their ability to promote innovation by using tools such as prizes and challenges to solve tough problems,"[1] which led to the development of the Challenge.gov platform. This site explains[2] that "With a challenge competition, you are defining the problem and framing the end-result you seek. Solvers enter the competition and have free reign and creativity to go about getting you the result you've described as the best possible outcome. If a solver meets your criteria and is judged a winner, you award them a prize (whether financial, incentive, or a combination) and your contractual relationship is complete."

A quick survey of the literature reveals that post-invention reward systems used to be the norm; they were progressively replaced by patents and procurement in the 19th century, only to come back to life "as a legitimate innovation incentive mechanism" in the past 15-20 years.[3] There is in fact a lot of current debate[4] on the efficacy of various models (prizes, grants, contracts) to promote innovation. For a researcher, participating in a challenge can be quite exciting and energizing. Moreover, supporting research with both grants and prizes seems preferable, especially since, at least in theory, "reward systems engender incentives to innovate without creating the monopoly power of intellectual property rights."[5]

Ironically, the renewed popularity of prize incentives is raising a challenge of its own: in order to compete, universities need to adapt to this new paradigm and find ways to support promising ideas and innovations before external funding is received to develop them.

Chikungunya

Chikungunya, which causes joint pain and fever,[6] is a viral disease transmitted to humans by infected mosquitoes. According to the WHO site,[7] the name means "to become contorted" and the first outbreak was reported in Tanzania in 1952. In 2013, chikungunya arrived in the Americas, where it has since then been infecting more than one million people in 44 (out of 55) countries.

3D-printed mosquito model given to challenge winners.

Forecasting the course of an outbreak is an important problem regularly faced by public health responders. Decisions (in my colleague's words, "whether to fly in surgeons, paliative care providers, or mortuary services") have to be made quickly and misjudgments have significant consequences. Mathematicians can help by developing a range of models that address both the short and long term dynamics of infectious diseases.

Predicting the spread of chikungunya fever

Heidi and I eventually decided to participate in the DARPA challenge. Last May, we were awarded first place[8] and received a $150,000 prize, which we will use to support our research activities. Our solution is extremely simple: it consists in representing the growth rate of the epidemic as a quadratic function of the number of cases, finding the

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[1]https://www.challenge.gov/about/

[2]https://www.challenge.gov/getting-started/

[3]F. Murray, S. Sternb, G. Campbell, A. MacCormack, Grand Innovation Prizes: A theoretical, normative, and empirical evaluation, Research Policy 41, 1779–1792 (2012)

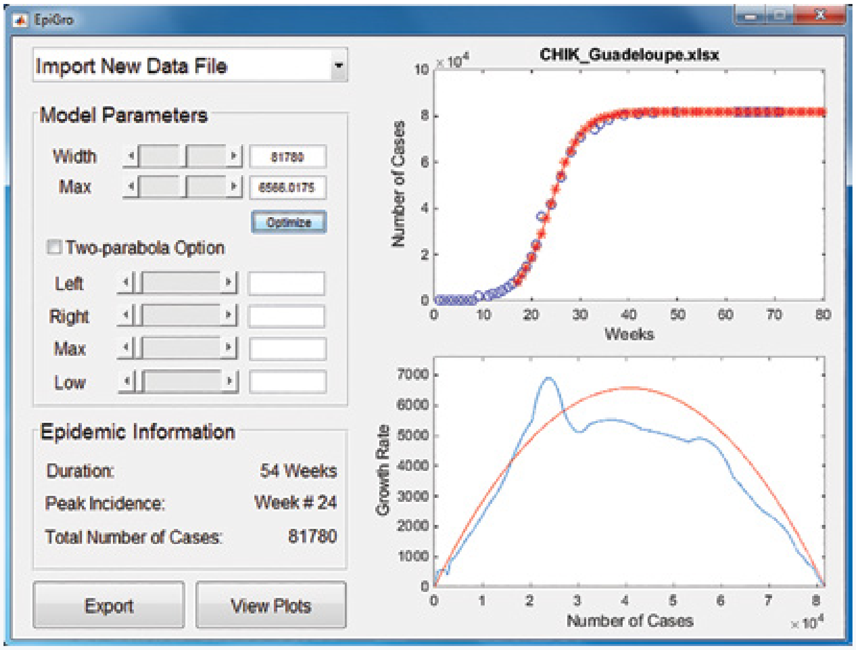
[4]Browse for instance the talk lineup for the conference Innovation Law Beyond IP held at Yale University in March 2014 (http://isp.yale.edu/event/innovation-law-beyond-ip)

[5]S. Shavell and T. van Ypersele, Rewards versus Intellectual Property Rights, Journal of Law and Economics XLIV, 525-547 (2001)

[6]See for instance http://www.cdc.gov/chikungunya/

[7]http://www.who.int/mediacentre/factsheets/fs327/en/

[8]http://www.darpa.mil/news-events/2015-05-27



EpiGro interactive tool showing epidemiological data for the 2014-15 chikungunya epidemic in Guadeloupe

parameters that best fit the reported data for each country, and making predictions on the basis of this simple model. In some instances, using a combination of two quadratic functions gave better results, revealing the presence of two phases (most likely due to geographic constraints) in the spread of the epidemic. At first, we were amazed that a model that did not include mosquito dynamics could still have predictive value, but we later realized that specific circumstances in the PAHO countries could justify our approach: the disease was new to the area, spread very quickly, and was carried by mosquitoes that were already in abundance in the region – dengue, an endemic disease in the Americas, is indeed transmitted by the same mosquitoes!

This realization was tremendously exciting because simplicity in modeling is both beautiful and practical. We are now working on a tool, currently in MATLAB (see figure), that implements the above approach for chikungunya and other diseases. EpiGro takes a file containing epidemiological data and gives a best guess for the future of a particular outbreak, assuming of course specific conditions are satisfied. We believe this has the potential to assist public health decision makers and thus guide mitigation efforts in certain circumstances.

The take-away message from this short article is that collaboration fosters innovation. Learning how to communicate with colleagues in other fields is a worthwhile investment, leading to synergistic activities that in turn provide unique training opportunities for graduate and undergraduate students. ▲

Joceline Lega *is a Professor of Mathematics with expertise in the modeling of nonlinear phenomena. She received her Ph.D. in theoretical physics from the University of Nice and was a researcher at CNRS (the French National Center for Scientific Research) before she joined the University of Arizona in 1997.*

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BIOGRAPHIES

Instructional Faculty

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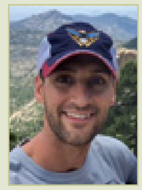

Michael Rossetti is from Canton, Ohio. He received a Master's Degree in Applied Mathematics from Case Western Reserve University in 2005. For the following year, he taught English at Sanda University in Shanghai, China. Since then, Mike has taught in the role of lecturer or instructor at Case Western Reserve University (one year), The University of Akron (six years), and Virginia Commonwealth University (one year) and spent one year as a Mathematics teacher and running coach at a private high school in Richmond, Virginia. Mike's wife, Allison, is an Assistant Professor in the Eller College of Management. Together, their hobbies include running, biking, hiking, and traveling.

PostDoctoral Fellows

Ashay Burungale is originally from India. After doing an undergrad in Indian Statistical Institute Bangalore, he obtained his doctorate from University of California Los Angeles in June 2015. He feels fortunate to be a student of professor Haruzo Hida. Number Theory and Modular Forms are his main mathematical interests. At the University of Arizona, he hopes to pursue new aspects with Professor Romyar Sharifi among others. Ashay has a keen interest in films. He is especially fond of Robert Bresson, Luis Buñuel, Hou-Hsiao Hsien, Abbas Kiarostami, Kenji Mizoguchi, Andrei Tarkovsky and Yasujiro Ozu.

Gabriela Jaramillo recently moved to Tucson from Minneapolis, where she received her Ph.D. from the University of Minnesota in June 2015. Her research focuses on exploring the role of defects in pattern forming systems using techniques from Functional Analysis. She is excited to be at the University of Arizona as a NSF Postdoctoral Research Fellow and is looking forward to expanding her interests in applied mathematics and computational methods. In her spare time she likes to read, cook, and go for long walks.

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