Integrating data with epidemic simulators to improve pandemic preparedness: Chikungunya in Colombia

All Hands BD2K meeting, 30 November 2016

Wilbert van Panhuis, MD PhD
wav10@pitt.edu
Pandemics are still a threat.

How to handle the infectious diseases threat

Daniel M. Gerstein
© Updated 1245 GMT (2045 HKT) June 3, 2016

As Ebola fades, a new threat
With health services devastated in the wake of Ebola, experts are bracing for a deadly measles outbreak in West Africa

The NEW ENGLAND JOURNAL of MEDICINE

Chikungunya Virus and the Global Spread of a Mosquito-Borne Disease
Edward W. Campion, M.D., Editor
Scott C. Weaver, Ph.D., and Marc Lecuit, M.D., Ph.D.

Zika Virus in the Americas — Yet Another Arbovirus Threat
Anthony S. Fauci, M.D., and David M. Morens, M.D.

An obscure mosquito-borne disease goes global
After racing through Oceania last year, the Zika virus is now spreading in the Americas
“An epidemic is one of the few catastrophes that could set the world back drastically in the next few decades. By building a global warning and response system, we can prepare for it and prevent millions of deaths.”

Bill Gates
Previous work: curating epidemic data

Unusable data

Easy-to-use data

- Digitization
- Extraction
- Re-design
- Annotation
- Dissemination

US data:
1888-present

WHO data:
1952-2010
Contagious Diseases in the United States from 1888 to the Present
Willem G. van Panhuis, M.D., Ph.D., John Grefenstette, Ph.D., Su Yon Jung, Ph.D., Nian Shong Chok, M.Sc., Anne Cross, M.L.I.S., Heather Eng, B.A., Bruce Y. Lee, M.D., Vladimir Zadorozhny, Ph.D., Shawn Brown, Ph.D., Derek Cummings, Ph.D., M.P.H., and David J. Read, M.D.

The Vaccination Effect: 100 Million Cases of Contagious Disease Prevented
By STEVE LOHR  NOVEMBER 27, 2013 5:00 PM  135
The role of influenza in the epidemiology of pneumonia

Sourya Shrestha¹,²,³, Betsy Foxman⁴, Joshua Berus⁵, Willem G. van Panhuis⁶, Claudia Steiner⁷, Cécile Viboud⁸ & Pejman Rohani⁸,¹⁰,¹¹

Received 31 March 2015


The New York Times

The Vaccination Effect: 100 Million Cases of Contagious Disease Prevented

By STEVE LOHR  NOVEMBER 27, 2013 5:00 PM  135
Persistent Chaos of Measles Epidemics in the Prevaccination United States Caused by a Small Change in Seasonal Transmission Patterns

Benjamin D. Dalziel¹, Ottar N. Bjørnstad², Willem G. van Panhuis³, Donald S. Burke⁴, C. Jessica E. Metcalf¹, Bryan T. Grenfell¹,⁵*
The age of vaccines

Tony Scully

Nature 507, S2–S3 (06 March 2014) | doi:10.1038/507S2a
Published online 05 March 2014
Region-wide synchrony and traveling waves of dengue across eight countries in Southeast Asia


*Department of Epidemiology, University of Pittsburgh Graduate School of Public Health, Pittsburgh, PA 15261; Laboratoire Maladies Infectieuses et Vecteurs Ecologie, Genetique, Evolution et Controle, Unité Mixte de Recherche 224 Centre National de la Recherche Scientifique-Institut de Recherche pour le Développement-Université de Montpellier, Institut de Recherche pour le Développement Montpellier, 34394 Montpellier, France; Oxford University Clinical Research Unit, Wellcome Trust Major Overseas Programme, National Hospital for Tropical Diseases, Hanoi 100000, Vietnam; Bureau of Epidemiology, Thailand Ministry of Public Health, Bangkok 10220, Thailand; High Impact Research, University of Malaya, 50603 Kuala Lumpur, Malaysia; Disease Control Division, Malaysia Ministry of Health, 62590 Putrajaya, Malaysia; Western Sussex Hospitals National Health Service Trust, Worthing Hospital, West Sussex BN11 2DH, United Kingdom; Department of Communicable Disease Control, Ministry of Health, Vientiane 0100, Lao People’s Democratic Republic; National Center for Laboratory and Epidemiology, Ministry of Health, Vientiane 0100, Lao People’s Democratic Republic; National Dengue Control Program, Cambodia Ministry of Health, Phnom Penh 12000, Cambodia; Department of Epidemiology, Vietnam National Institute of Hygiene and Epidemiology, Hanoi 100000, Vietnam; Centers for Disease Control, Taiwan Ministry of Health and Welfare, Taipei City 10050, Taiwan; Environmental Health Institute, Singapore National Environment Agency, Singapore 228231; National Epidemiology Center, Philippines Department of Health, Manila 1003, Philippines; National Center for Disease Prevention and Control, Philippines Department of Health, Manila 1003, Philippines; Viral Disease Branch, Walter Reed Army Institute of Research, Silver Spring, MD 20910; Department of Virology, US Armed Forces Research Institute of Medical Sciences, Bangkok 10400, Thailand; Dengue Vaccine Initiative, International Vaccine Institute, Seoul, 08826 Korea; Department of Biology, University of Florida, Gainesville, FL 32610; and Emerging Pathogens Institute, University of Florida, Gainesville, FL 32610

The Vaccination Effect: 100 Million Cases of Contagious Disease Prevented

By STEVE LOHR NOVEMBER 27, 2013 5:00 PM 135
Active and growing user community

www.tycho.pitt.edu

33,000 unique web visitors
200,000 page views
5000 datasets downloaded
15 peer-reviewed papers
“Project Tycho, for example, unlocks CDC data on contagious diseases which goes back all the way to 1888.”

(Secretary Sebelius)

Reimagining Health Care Delivery: Remarks to the Aspen Institute Care Innovation Summit
(Washington DC, Feb 27 2014)
Data integration to prepare for epidemics

- Data and metadata not machine-interpretable
- No central access to datasets

Colombia CHIKV case data
Mosquito occurrence data
Mosquito control data
CHIKV transmission dynamics
- Simulators mathematically define how different datasets (subsystems) interact to create an epidemic.

- Simulators provide the “recipe” for how to integrate diverse datasets into one representation of an epidemic.
Each simulator integrates specific data

**Controlling Dengue with Vaccines in Thailand**

- Dengue
- Thailand
- Vaccines

**Countering the Zika epidemic in Latin America**

- Zika
- Brazil
- No intervention

**Measuring the impact of Ebola control measures in Sierra Leone**

- Ebola
- Sierra Leone
- Expanding beds
Simulator-derived data model

Simulators

Standard data model (XSD)

- Standard vocabulary
- Semantically and syntactically precise
- Machine-readable information
- Web services for data and epidemic simulation
Re-represented chikungunya data

Chikungunya Epidemics

Summary of Information in the Chikungunya Collection

1. 1952, Tanzania [JSON] [XML]
2. 2005, Reunion [JSON] [XML]
3. 2005, Mayotte [JSON] [XML]
4. 2007, Italy [JSON] [XML]
5. 2012, Cambodia [JSON] [XML]
Standardized data integrated by simulators

Standardized data

Available simulators (machine-readable characterization)

Simulated epidemic scenarios
Agent-based simulation of Chikungunya

Real population represented: Colombia

45 Million agents
10 Million households, schools, and workplaces

Camargo G, Van Panhuis, et. al., in review.
Chikungunya control using previous dengue data

Simulated scenarios with and without mosquito control

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Day 125</th>
<th>Day 250</th>
<th>Day 350</th>
<th>Day 500</th>
</tr>
</thead>
<tbody>
<tr>
<td>No vector control</td>
<td><img src="image1" alt="Map" /></td>
<td><img src="image2" alt="Map" /></td>
<td><img src="image3" alt="Map" /></td>
<td><img src="image4" alt="Map" /></td>
</tr>
<tr>
<td>Vector control in all 770 municipalities</td>
<td><img src="image5" alt="Map" /></td>
<td><img src="image6" alt="Map" /></td>
<td><img src="image7" alt="Map" /></td>
<td><img src="image8" alt="Map" /></td>
</tr>
<tr>
<td>Vector control in 301 dengue municipalities</td>
<td><img src="image9" alt="Map" /></td>
<td><img src="image10" alt="Map" /></td>
<td><img src="image11" alt="Map" /></td>
<td><img src="image12" alt="Map" /></td>
</tr>
</tbody>
</table>

1.1M cases
0 cases prevented

481K cases
656K cases prevented

651K cases
487K cases prevented

Infected cases
Recovered cases

Camargo G, in review
Future: Population health data ecosystem

1. Expand collections of machine-readable data relevant for pandemics, from existing data systems and studies funded by a wide range of NIH and other funders (NIGMS, NIAID, Fogarty, Gates Foundation, UK, EU, etc): project push and community adoption of standards.

2. Expand collections of existing machine-interpretable simulators for epidemic diseases (e.g. mosquito-borne, respiratory, diarrheal, and HIV) created by scientists funded by a wide range of funders.

3. Create new technology for automatic data integration that connects datasets with simulators, for the purpose of simulating specific epidemic scenarios.

4. Infrastructure for machine-readable data and simulators as example of a Population Health Data Commons for pandemic preparedness.

5. Translate infrastructure and technology for epidemic diseases to other infectious and non-infectious diseases (e.g. cancer).
Acknowledgements

Mike Wagner, MD PHD
Professor of Biomedical Informatics and Intelligent Systems
Mentor

Greg Cooper, MD PhD
Professor of Biomedical Informatics and Intelligent Systems
Co-Mentor

Mark Roberts, MD
Professor of Health Policy and Management, and Medicine
Co-Mentor

Mike Becich, MD PhD
Professor and Chair of Biomedical Informatics

Donald Burke, MD
Dean, Graduate School of Public Health

Faculty, Staff, and Students
Jeremy Avigad, Carnegie Mellon University • Bill Hogan, University of Florida • John Levander, University of Pittsburgh • Max Sibilla, University of Pittsburgh • Nick Millet, University of Pittsburgh • Anne Cross, University of Pittsburgh • Sharon Crow, University of Pittsburgh • Dan Bain, University of Pittsburgh • Marc Choisy, Institute de la Recherche pour le Développement • Derek Cummings, University of Florida • Ernesto Marques, University of Pittsburgh

Funders and Partners
National Institutes of Health BD2K (1K01ES026836), and Models of Infectious Disease Agent Programs (U54GM088491) • Benter Foundation • Bill & Melinda Gates Foundation (#49276 and #OPP1091931) • Brazil Ministry of Health • Cambodia Ministry of Health • Council of State and Territorial Epidemiologists • Digital Divide Data • Johns Hopkins University Bloomberg School of Public Health • Laos Ministry of Health • Pan American Health Organization • Pittsburgh Supercomputing Center • Taiwan Ministry of Health • Thailand Ministry of Health • University of Pittsburgh Department of History • University of Pittsburgh School of Information Sciences • U.S. Department of Health & Human Services • U.S. Open Government Initiative • Vietnam Ministry of Health • World Health Organization