The RAPIDD Ebola forecasting challenge special issue

Preface

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Published in:
Epidemics

DOI:
10.1016/j.epidem.2017.10.003
10.1016/j.epidem.2017.10.003

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Simonsen, L., Viboud, C., Chowell, G., & Vespignani, A. (2018). The RAPIDD Ebola forecasting challenge special issue: Preface. *Epidemics*, *2018*(22), 1-2. https://doi.org/10.1016/j.epidem.2017.10.003, https://doi.org/10.1016/j.epidem.2017.10.003

Epidemics 22 (2018) 1–2

Contents lists available at ScienceDirect

Epidemics

journal homepage: www.elsevier.com/locate/epidemics

Editorial

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Interest in disease forecasting is growing, stimulated by the continued threat of emerging infections, increased modeling capabilities, and a more porous interface between the modeling community and policy experts who make decisions to roll out interventions (Chretien et al., 2015a). Forecasting competitions are common in the field of meteorology and climate, but have just started to percolate the field of disease modeling. Key examples include the multi-year seasonal flu contest initiated by the US CDC in 2015, the dengue challenge organized by NOAA, and the chikungunya challenge led by DARPA (DARPA, 2015; Biggerstaff et al., 2016; NOAA, 2015). In this special issue, we describe the Ebola forecasting challenge led by the US National Institute of Health in 2015–2016, as part of their Research And Policy in Infectious Disease Dynamics (RAPIDD) program.

The RAPIDD Ebola forecasting challenge was launched in the aftermath of the 2014–2015 West African Ebola outbreak, during which a large number of real-time modeling approaches were used to generate useful but sometime conflicting predictions due to the varying outcomes, methodological assumptions and scenarios considered (Chretien et al., 2015b). The goals of this challenge were to compare the prediction accuracy of different Ebola transmission models while exploring a range of data availability, measurement error, and epidemiological complexity in a controlled manner. The Ebola forecasting challenge was unique in that it relied on synthetic outbreak data generated by a detailed mechanistic disease model, while other challenges have relied on empirical outbreak data thus far. The challenge considered a variety of prediction targets that are relevant to policy-making, ranging from short-term incidence forecast (1–4 week ahead) to medium-term projections of final size, peak size, and peak timing, and inference of natural history parameters. This special issue describes the implementation, results, and conclusions of this challenge, and discusses the future of disease forecasts and forecasting challenges.

The first article of the special issue describes the Ebola model used to generate the synthetic epidemiological datasets shared with challenge participants, representing 4 plausible epidemiological scenarios and data granularity inspired from the 2014-15 West African outbreak. The paper also delineates the situational narratives and web interface created for the challenge. Articles 2–9 focus on the individual models developed by the eight teams participating to the challenge, representing a diverse range of model structures, assumptions, and fitting procedures. Each paper provides a detailed description of the models, their outputs, and forecasting performance, as well as a discussion of limitations and potential refinements. The last article provides a synthetic view of forecasting results across all participating teams, including summary statistics of performances across models and ensemble predictions, and ends with a discussion of the future of forecasting challenges.

The unique feature of the Ebola challenge was its reliance on synthetic data, allowing for careful control of data availability and noise level, which previous challenges had been unable to do in a controlled manner. This unusual design helped demonstrate the importance of data quality and awareness of planned interventions for increased forecasting performance. A drawback of this design, however, is the failure to provide detailed insights on the dynamics of a real outbreak, even though the data may be inspired by a real-life infectious disease crisis. Further, the data-generating model needs to be realistic for the findings to be relevant to forecasting of future outbreaks.

A number of the conclusions of this challenge align with those of previous challenges (DARPA, 2015; Biggerstaff et al., 2016; NOAA, 2015). In particular, we found that model complexity did not scale with prediction accuracy. We saw a trade-off between short-term forecasts, for which models with few parameters and fitted to a recent subset of the data worked best, vs fully mechanistic frameworks that could provide more spatial details, predict at longer time horizons, and evaluate the impact of interventions. Reassuringly, we found that ensemble predictions outperformed any participating model, by integrating the uncertainty of individual models and providing an edge against the occasional deviation of even the best models.

How do we best prepare the modeling community for the next infectious disease crisis? There is no ideal drill, but synthetic challenges can contribute to strengthening coordination between modeling groups and generate a collaborative spirit that can be useful when the next outbreak hits. Forecasting challenges are best conducted in peace time, so that the details of data sharing, model fitting, and computation of ensemble predictions can be carefully worked out. On the other hand, in the context of a challenge, the involvement of participating teams may not be as intense as in real infectious disease crisis, where providing accurate model forecasts can have a true impact on policy decisions and help save lives.

The RAPIDD Ebola Forecasting challenge fits within a trend of increased appetite for infectious disease forecasts from policy-makers, and a need for systematic model comparisons to provide robust projections of the impact of new interventions. To single out a few examples, recent large-scale comparisons have focused on the roll-out of the rotavirus and dengue vaccines (Pitzer et al., 2012; Flasche et al., 2016), increased antiviral therapy for HIV (Eaton et al., 2012), or increased diagnosis and treatment for neglected tropical diseases (Hollingsworth and Medley, 2017). Forecasting "challenges" have a slight edge over traditional model comparison projects, in that they are perceived as friendly competitions, which scientists naturally gravitate towards. Overall, multi-team challenges and model comparisons stem from the recognition that no individual model is right and

http://dx.doi.org/10.1016/j.epidem.2017.10.003

Available online 24 October 2017

that consensus model outputs are needed to guide public health responses. Again, the field of meteorology is decades ahead of epidemiology in this respect, as illustrated most notably by the Inter-governmental Panel on Climate Change predictions (http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=524).

This special issue on Ebola forecasting intersects nicely with previous Special issues of *Epidemics* on model comparisons for neglected tropical diseases (Hollingsworth and Medley, 2017), and challenges in infectious diseases dynamics (Lloyd-Smith et al., 2015). Common emergent themes include the need for development of standardized methods for model comparisons and validation, handling of uncertainty, availability and accuracy of empirical data, development of portfolio of models tailored to different types of pandemic threats, and the interface between models and policy. Most inspiringly perhaps is the spirit of collegiality and collaboration that characterizes the large group projects described in these three special issues.

In conclusion, we anticipate that the RAPIDD Ebola Forecasting special issue will stimulate further synthetic and empirical infectious disease challenges and systematic model comparisons. These large-scale projects represent an intense amount of work from participating teams, with typically little or no funding. However, we believe they represent an important step towards improving the link between policy and modeling. Emerging and re-emerging infectious diseases will continue to present new threats, and we hope that this body of work will inspire a new crop of scientists to collaboratively advance the field of infectious disease forecasting.

We dedicate this special issue to our dear colleague, Dr Ellis F Mc Kenzie, who shepherded the RAPIDD modeling program during 2007–2016. He was a prudent advocate for infectious disease forecasting and the Ebola forecasting challenge would not have been possible without his continued support and gentle guidance

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