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Using Data-driven Agent-based models for Forecasting Emerging Infectious Diseases

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Abstract

Producing timely, well-informed and reliable forecasts for an ongoing epidemic of an emerging infectious disease is a huge challenge. Epidemiologists and policy makers have to deal with poor data quality, limited understanding of the disease dynamics, rapidly changing social environment and the uncertainty on effects of various interventions in place. Under this setting, detailed computational models provide a comprehensive framework for integrating diverse data sources into a well-defined model of disease dynamics and social behavior, potentially leading to better understanding and actions. In this paper, we describe one such agent-based model framework developed for forecasting the 2014-15 Ebola epidemic in Liberia, and subsequently used during the Ebola forecasting challenge. We describe the various components of the model, the calibration process and summarize the forecast performance across scenarios of the challenge. We conclude by highlighting how such a data-driven approach can be refined and adapted for future epidemics, and share the lessons learned over the course of the challenge.

Keywords: Emerging infectious diseases; Agent-based models; Simulation optimization; Bayesian calibration; Ebola;

1. Introduction

In the latter half of 20th century, there was a prevailing optimism about humanity's preparedness against infectious diseases. Nobel prize winning virologist F.M.Burnet echoed the opinion of researchers and laymen alike, when he said *"the most likely forecast about the future of infectious disease is that it will be very dull."* [1] The confidence seemed justified given the development of antibiotics and vaccines, recent successes against polio and smallpox, etc. However, it was short-lived, with the emergence of HIV/AIDS in Africa, which has since grown into one of the greatest global health concerns of our time. Less than 20 years into the 21st century, we have been impacted by a series of infectious diseases such as SARS (2003), H1N1 (2009), Ebola (2014) and more recently Zika (2016).

With increased global connectivity, intermixing of human and animal habitats, and the looming threat of climate change, such threats will become more common [2]. As in the case of Ebola, healthcare infrastructure, especially in densely populated and developing countries, will be severely stressed [3]. Generating reliable spatio-temporal forecasts, both short term and long term, will help stimulate and guide global efforts where and when required. Owing to limited understanding of the emerging infectious disease, vaccines development may not be swift, thus initial responses still need to rely on traditional epidemic control measures like isolation of cases and social distancing to curb the epidemic. The ability to evaluate and compare different behavioral interventions will be immensely valuable.

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