Calibration & Forecasting for Infectious Diseases

Collaborative work done at the Network Dynamics and Simulation Science Laboratory (NDSSL), Virginia Bioinformatics Institute, Virginia Tech, Blacksburg, VA 24061

VirginiaTech
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Introduction

- Infectious disease dynamics are inextricably linked to infrastructure
- Human mobility and contact patterns dictated by
  - Transport: road/rail routes, airways, public transits
  - Social: housing, schools, hospitals
  - Business: workplaces, shopping malls, entertainment locations
- Predicting the disease evolution can help
  - plan appropriate public interventions (e.g., school closures)
  - deploy critical healthcare support (e.g., emergency treatment units)

Goal

Given the early evolution of an epidemic (daily/weekly confirmed case counts) from varied surveillance sources, develop a methodology to provide reliable forecasts

Challenges

- Handle scarce and inherently noisy data from varied surveillance sources
- Build detailed agent-based models leveraging the underlying contact network
- Calibrate the disease transmission model with appropriate disease parameters

Calibration Methodology

- Optimization framework: Nelder-Mead search
- Objective function: $\min_\theta \frac{1}{R}\sum_{r=1}^{R}(\sum_{i=1}^{N}\alpha^{N-i}|Y_{\theta,r}(i)-X(i)|)$

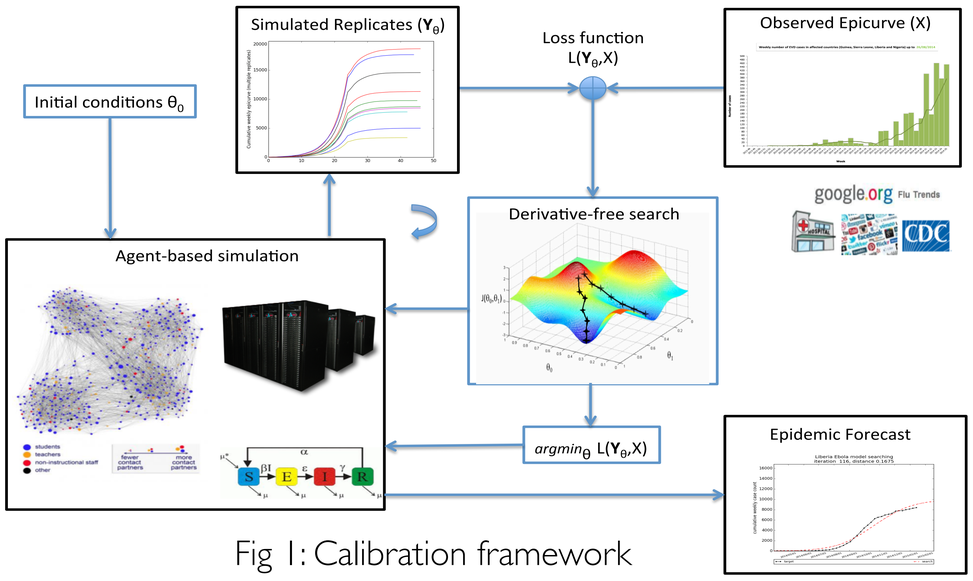

Fig 1: Calibration framework

Sample scenario

- 2014 Ebola outbreak in West Africa
- Largest Ebola outbreak yet: 28000 cases; 10500 deaths (WHO, Sept 2015)
- Severe load on local infrastructure and global emergency response

Synthetic population (Liberia): 4M nodes, 80M edges*
Disease model: SEIR with hospitalization and funeral [Legrand et al. 2007]
Implemented using EpiFast simulation tool developed at NDSSL

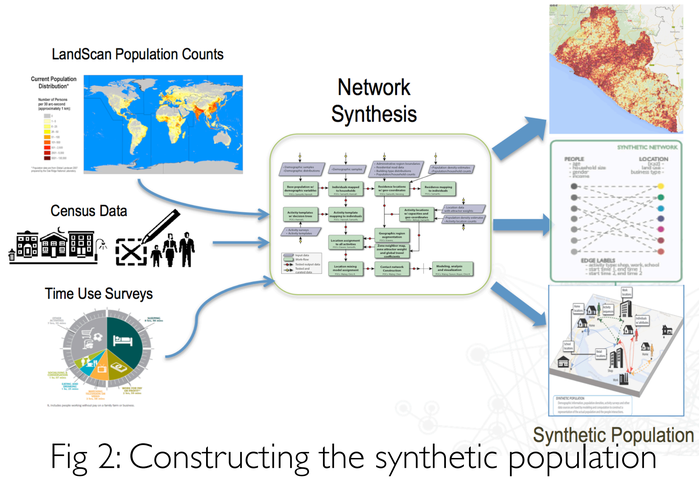

Fig 2: Constructing the synthetic population

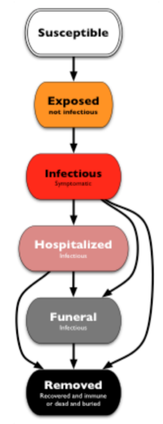

Fig 3: Disease model

Results

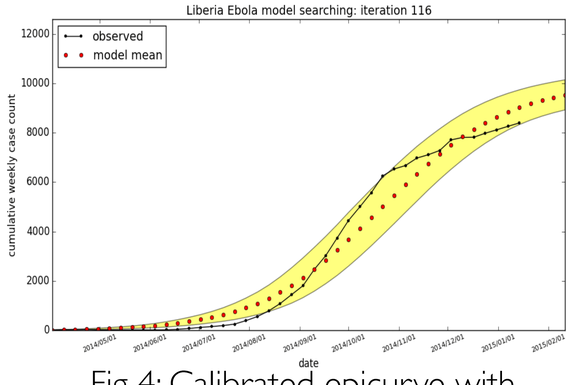

Fig 4: Calibrated epicurve with variance estimate

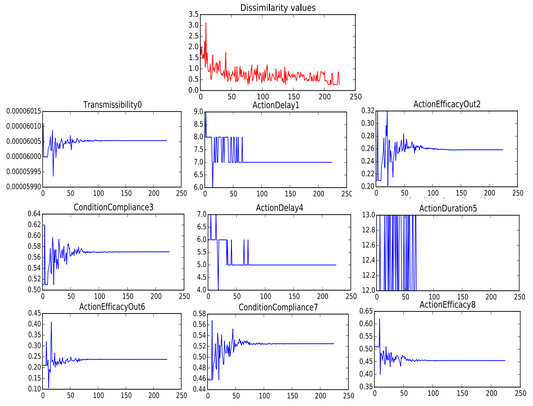

Fig 5: Parameter evolution during N-M search

Current focus

- Spatial calibration: calibrating for county-wise epicurves
- Bayesian calibration: output a distribution over disease parameters

* *Data available at: https://www.vbi.vt.edu/ndssl/featured-projects/ebola/*