Temporospatial model of measles epidemics in Vietnam

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Introduction

- Measles epidemics continue to persist in Vietnam despite an effective vaccine
- Differential vaccination coverage across districts contributes to reemerging outbreaks

Research Objectives

- Quantify the connectivity of districts across Vietnam based on individual movement data
- Develop a temporospatial model of measles epidemics
- Implement a program to efficiently simulate measles outbreaks across the network of districts

Methods

- District-level connections parameterized by colocation data from Facebook’s Data for Good
- District demographics based on Vietnam census data (2019)
- SEIR metapopulation model
- Approximate tau-leaping algorithm for SEIR metapopulation simulator

Temporospatial Model

SEIR Metapopulation Dynamics

$$\frac{dS_i}{dt} = -S_i \sum_j \beta_{ij} \frac{I_j}{N_j}$$

$$\frac{dE_i}{dt} = S_i \sum_j \beta_{ij} \frac{I_j}{N_j} - \sigma E_i$$

$$\frac{dI_i}{dt} = \sigma E_i - \gamma I_i$$

$$\frac{dR_i}{dt} = \gamma I_i$$

S: susceptible; I: infectious; E: infected; R: recovered

$\frac{1}{\sigma} = 7$ days is the latency period

$\frac{1}{\gamma} = 7$ days is the recovery period

$\beta_{ij} = \gamma R_{0ij}$ is the transmission rate from district j to district i

Transmission Rate Parameterization

$$R_{0ij} = R_{0\,Hanoi} \frac{C_{ij} N_j}{C_{Hanoi-Hanoi} N_{Hanoi}}$$

C_{ij} is colocation probability for district i and district j

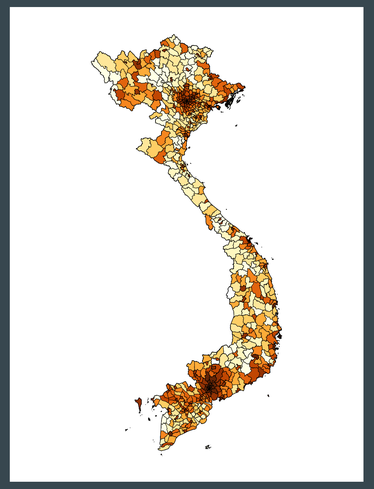
N_j is population in district i

$C_{Hanoi-Hanoi}$ is the intra-district colocation probability for the densest district in Hanoi

Model Visualizations

Vietnam Mobility Map. Lines represent connections between districts with darker lines indicating stronger mobility of residents between two districts.

- Strong intra-province connectivity with weak inter-province connectivity
- Transport centers in Hanoi, Ho Chi Minh and Da Nang



Vietnam ROI Map. Each district is assigned a color with darker colors corresponding to higher risks of infection for residents.

- Positive correlation between district-level population density and risk of infection (ROI)
- ROI is significantly higher around the transport centers of Hanoi and Ho Chi Minh

Next steps

- Modify simulator to efficiently scale with larger population sizes and greater number of districts
- Simulate the SEIR metapopulation model with varying vaccine coverage parameterizations to assess efficacy of different vaccination protocols

Conclusions

- Individual-level mobility data suggests that transport centers with a high degree of intra- and inter-district connections will have a higher ROI
- The computational barriers to exact stochastic simulation of disease epidynamics may limit applicability of this model to larger networks

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