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.

SEIR Metapopulation Dynamics

\[
\begin{align*}
\frac{dS_i}{dt} &= -S_i \sum_j \beta_{ij} I_j/N_j \\
\frac{dE_i}{dt} &= S_i \sum_j \beta_{ij} I_j/N_j - \sigma E_i \\
\frac{dI_i}{dt} &= \alpha E_i - \gamma I_i \\
\frac{dR_i}{dt} &= \gamma I_i
\end{align*}
\]

- S: susceptible; I: infectious; E: infected; R: recovered.
- $1/\sigma = 7$ days is the latency period.
- $1/\gamma = 7$ days is the recovery period.
- $\beta_{ij}$ is the transmission rate from district j to district i.

Transmission Rate Parameterization

\[ R_{0ij} = R_0_{\text{Hanoi}} \frac{C_{ij} N_j}{C_{\text{Hanoi-Hanoi}} N_{\text{Hanoi}}} \]

- $C_{ij}$ is colocation probability for district i and district j.
- $N_j$ is population in district i.
- $C_{\text{Hanoi-Hanoi}}$ is the intra-district colocation probability for the densest district in Hanoi.

Model Visualizations

- Strong intra-province connectivity with weak inter-province connectivity.
- Transport centers in Hanoi, Ho Chi Minh and Da Nang.
- 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 epidemics may limit applicability of this model to larger networks.

Acknowledgements

I would like to thank my supervisor, Dr. Marc Choisy for advising me throughout this project and for his ongoing support and advice. Furthermore, I truly appreciate OUCRU and CHW for supporting the internship amidst the difficulties posed by the global pandemic.