Reaction-diffusion spatial modeling of COVID-19 in Chicago

Trent Gerew

Illinois Institute of Technology

August 27, 2021

Outline

1. The COVID Problem
2. Project Context and Objectives
3. Social and Community Connections
4. Current Work

Outline

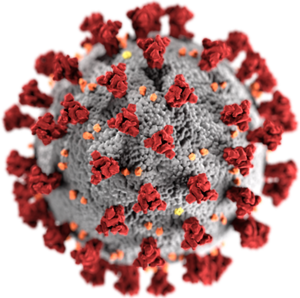
The COVID Problem

Identified in Wuhan, China in December 2019.
Caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).

In the United States alone, we currently have

- **37,768,911** total cases
- **626,833** total deaths

(Source: CDC)



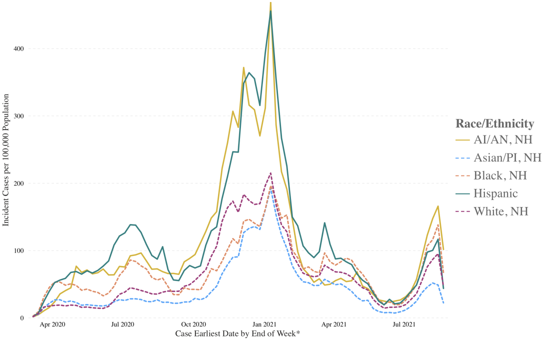
The COVID Problem

Transmission by exposure to infectious respiratory fluids:

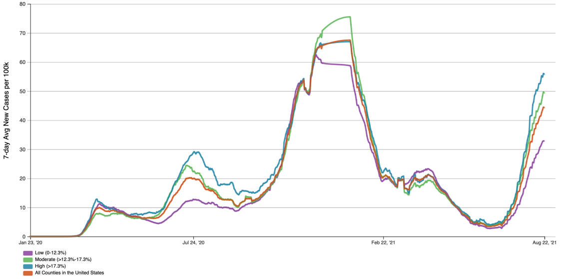
1. Inhalation of virus
2. Deposition of virus on exposed mucus membranes
3. Touching mucous membranes with soiled hands contaminated with virus

The COVID Problem

COVID-19 weekly cases per 100,000 population by race/ethnicity, United States



COVID-19 weekly case rate per 100,000 population by percentage of county population in poverty, United States



(Source: CDC)

Outline

Project Context and Objectives

Why make a mathematical study of COVID-19?

An epidemic model provides . . .

- a convenient summary of the data
- insight into the underlying processes of the disease spread
- a testing ground for assessing control procedures

Project Context and Objectives

Models of infectious diseases are usually variations on the **Kermack-McKendrick model** (1927).

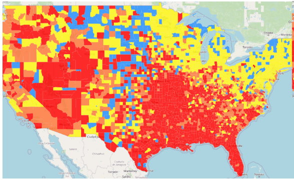
Usual assumptions:

- Population is *homogeneous*
- Transmission is spatially independent

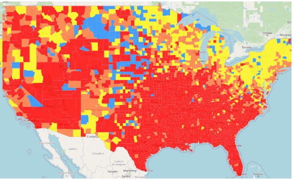
Project Context and Objectives

These assumptions don't match reality!

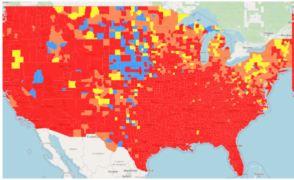
Level of community transmission by county (Source: CDC)



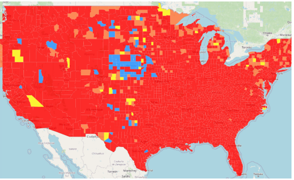
(a) 7/22/2021



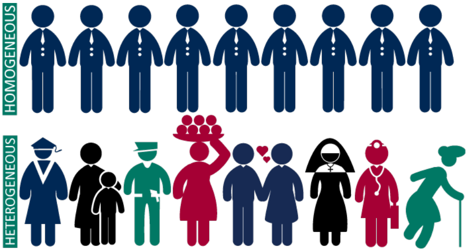
(b) 7/29/2021



(c) 8/8/2021



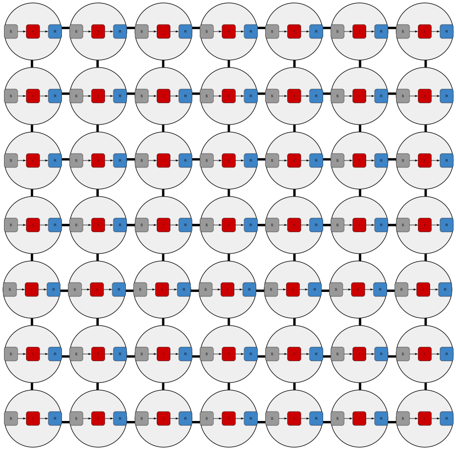
(d) 8/21/2021



Project Context and Objectives

Idea: Use reaction-diffusion to build a spatially explicit model.

- The data clearly shows a diffusive pattern
- Spatial dependence can approximate demographic differences
- Spatially dependent data exists for many scales and regions



Outline

Social and Community Connections

Summer 2020 context: IPRO with David Eads (NPR) to identify *demographic trends* in COVID-19.

- How does the impact of COVID-19 (in Chicago) depend on **age** and **race/ethnicity**?

Present context: COVID-19 is still here. Where is it impacting and why?

- Does **community structure** play a role?
- How effective are **vaccines**? (Or what is thwarting them?)
- Are **care facilities** properly allocated?
- *Other ideas?*

Goal: Can we design a model to answer these questions?

Outline

Current Work

Idea:

1. Define a *local* process that occurs locally at every point in space.
2. Determine suitable *local* parameters (e.g., transition rates).
3. Define the characteristics of the *physical space* (e.g., population density).
4. Integrate the local process over the physical space.
5. Determine suitable *physical* parameters (e.g., transmission rates).

Progress:

- Start by defining a toy model: **S**usceptible, **I**nfected, **R**emoved.
- Local parameters fitted using data from the Chicago Data Portal.
- Spatial characteristics defined using data from the U.S. Census Bureau.
- Numerical spatial integration is a work in progress.