Reaction-diffusion spatial modeling of COVID-19 in Chicago

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August 27, 2021

Outline

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

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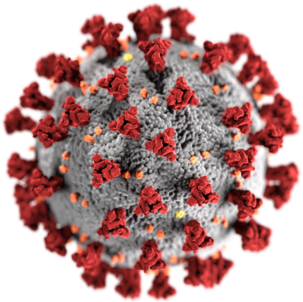
The COVID Problem

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)

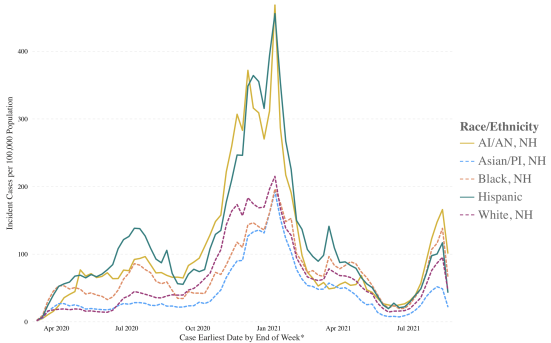
The COVID Problem

Transmission by exposure to infectious respiratory fluids:

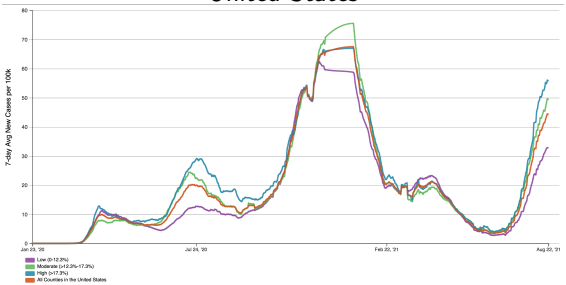
1. Inhalation of virus
2. Deposition of virus on exposed mucous membranes
3. Touching mucous membranes with soiled hands contaminated with virus

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)

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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).

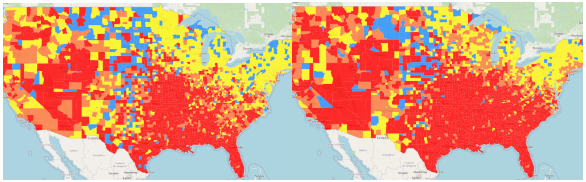
Usual assumptions:

- Population is *homogeneous*
- Transmission is spatially independent

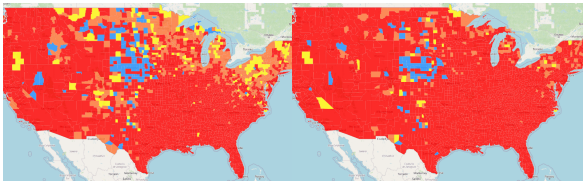
Project Context and Objectives

These assumptions don't match reality!

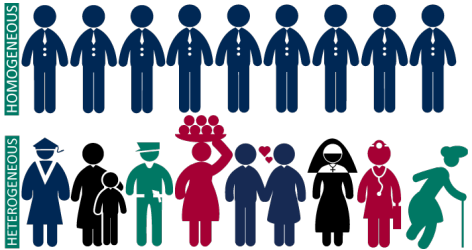
Level of community transmission by county (Source: CDC)



(a) 7/22/2021 (b) 7/29/2021



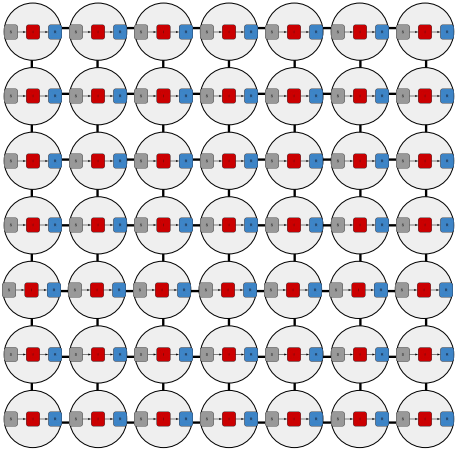
(c) 8/8/2021 (d) 8/21/2021



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



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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?

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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.