COVID-19 ICU Capacity Simulation Model for New Jersey

Overview

This project implements a sophisticated SEICICUR (Susceptible-Exposed-Infectious-Confirmed-ICU-Recovered) epidemiological model to simulate and analyze COVID-19 transmission dynamics and ICU capacity requirements across New Jersey counties. The model specifically focuses on predicting ICU utilization and identifying potential capacity constraints in the healthcare system.

Project Structure

```
├── sim.py                    # Main simulation model implementation
├── data/                     # Directory for processed data
├── figures/                  # Directory for generated plots and visualizations
├── scripts/                  # Directory for auxiliary scripts
│   ├── aggregate.py          # Data aggregation script
│   ├── create_epc.py         # Exceedance Probability Curve generation
├── county_populations.csv    # County-wise population data
├── hospital_resources.csv    # Hospital resource availability data
├── nj_county_pop.csv         # New Jersey county population data
├── nj_cases_deaths_2020.csv  # COVID-19 cases and deaths data for 2020
├── nj_cases_by_county.csv    # County-wise COVID-19 case data
└── nj_hosp_resources.csv     # Hospital resource data for New Jersey
```

Model Description

The SEICICUR model is an extension of the traditional SEIR model, incorporating additional compartments to better represent the progression of COVID-19 cases through the healthcare system. The model includes:

- Susceptible (S)
- Exposed (E)
- Infectious (I)
- Confirmed (C)
- ICU (ICU)
- Recovered (R)

Key parameters include:

- β (beta): Transmission rate
- σ (sigma): Rate of progression from exposed to infectious
- γ (gamma): Recovery rate for non-ICU cases
- φ (phi): Proportion of confirmed cases requiring ICU care
- μ (mu): ICU discharge rate
- ξ (xi): Case confirmation rate

Dependencies

- Python 3.x
- pandas
- numpy
- scipy
- matplotlib
- seaborn
- joblib
- tqdm

Data Sources

The project utilizes various data sources for New Jersey:

- County-level population data
- COVID-19 case and death statistics
- Hospital resource availability
- ICU capacity information

Usage

1. Ensure all required dependencies are installed
2. Place the required data files in the project root directory
3. Run the simulation using:

```
python sim.py
```

Output

The simulation generates:

- ICU capacity utilization predictions
- Peak ICU usage estimates
- Probability of exceeding ICU capacity
- Various visualization plots in the `figures/` directory

Analysis Capabilities

- County-wise COVID-19 transmission dynamics
- ICU capacity assessment
- Healthcare resource utilization forecasting
- Risk analysis for healthcare system overload

Scripts

The `scripts/` directory contains utility scripts for data processing and visualization:

aggregate.py

A data aggregation script that:

- Combines simulation results from multiple counties (Atlantic, Camden, Cape May)
- Calculates aggregate ICU metrics including:
  - Combined maximum ICU usage
  - Peak ICU ratios
  - Days exceeded capacity
  - Combined capacity utilization
- Generates consolidated datasets for multi-county analysis

create_epc.py

An Exceedance Probability Curve (EPC) generation script that:

- Creates visualizations of ICU capacity exceedance probabilities
- Generates step plots for comparing ICU usage across counties
- Provides visual analysis of the likelihood of exceeding ICU capacity
- Uses color-coded plotting for different counties (Atlantic, Camden, Cape May)

These scripts are essential for post-processing simulation results and creating visualizations for risk assessment and capacity planning.

Data Files

The project uses several CSV files containing New Jersey COVID-19 and healthcare data:

COVID-19 Case Data

- `nj_cases_deaths_2020.csv` : Daily COVID-19 case and death counts
  - Time series data from March 2020
  - Includes: date, county, cumulative cases, cumulative deaths
  - FIPS codes for geographic identification
- `nj_cases_by_county.csv` : Detailed county-level case data
  - County-specific COVID-19 case information
  - Used for county-level transmission analysis

Healthcare Resource Data

- `hospital_resources.csv` : Hospital capacity information
  - Licensed, staffed, and ICU bed counts
  - Ventilator availability
  - Age demographic breakdowns (65-85+ years)
  - County-specific healthcare infrastructure data
- `nj_hosp_resources.csv` : New Jersey hospital resource tracking
  - Specific to NJ healthcare facilities
  - ICU capacity metrics
  - Resource utilization data

Population Data

- `county_populations.csv` : Basic population statistics
  - County-level population counts
  - Used for per capita calculations
- `nj_county_pop.csv` : Detailed NJ population data
  - 2020 population figures for all NJ counties
  - Used for demographic modeling parameters

All data files are structured in CSV format and are essential for:

- Model calibration
- Parameter estimation
- Capacity planning
- Risk assessment
- Results validation

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Citation

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