LTM Enhancement for COVID-19 Modeling

< CSE 8803 >

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Motivation/Introduction

- **Addressing a Global Challenge**
  - critical need for advancing modeling in understanding and predicting the spread of COVID-19
- **Improving Predictive Models**
  - limitations with existing models (and need for a more nuanced approach to capture disease spread complexity)
- Innovating with Linear Threshold Model (LTM)
  - LTM enhancement to better account for individual-level variability in susceptibility to infection
- Combining LTM with SIR and other models
  - refining predictive accuracy
- **Aiding public health decisions & strategies** (practical significance of data-driven approach)

Problem Definition

Simulate the spread of COVID-19 pandemic by integrating LTMs with more complex epidemiological models

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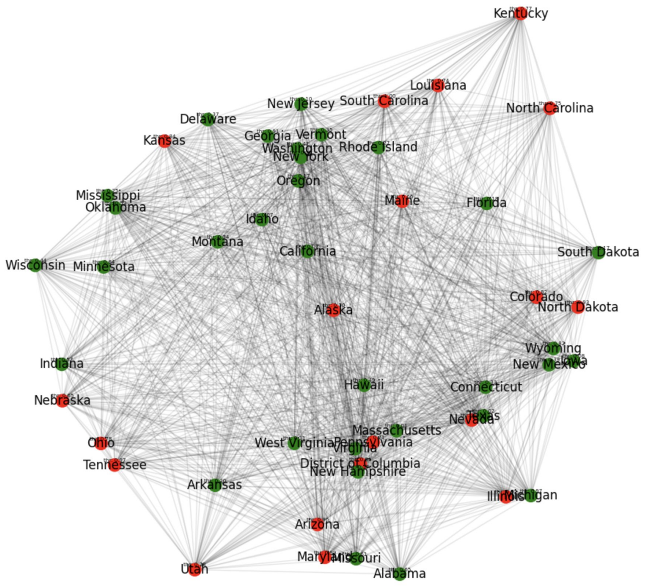
Linear Threshold Model (LTM) Overview

- Basic Principle
  - describes how individuals in a network adopt new behaviors based on their **neighbor's influence** (can vary, represented by weights in network)
- Individual **Binary Choices** (to adopt or not to adopt)
- **Threshold** Concept
  - specific proportion of neighbors who must adopt a behavior before they will follow
- **Cumulative Influence**
  - individual behavior changes only when cumulative influence of neighbors exceeds their threshold
- Useful in predicting **behavior spread**



Methodology

1. **Network Representation**
   a. Create a graph structure (50 connected nodes to represent US states and physical distances between them as edge weights)
2. **Influence Calculation**
   a. Assign thresholds randomly
   b. Initialize set of active/inactive nodes
3. **Iterative Spread Process**
   a. Repeat activation process until no new activations occur
4. **Model Layering** (combining with SI, SIR, & SIRS models)
   a. Integrate LTM thresholds and activations as a measure of infection rate and transmission probabilities
5. **Simulation and Enhancement**
   a. Modify SIR rates based on LTM dynamics to reflect social influence on disease spread
6. **Validation**

Data

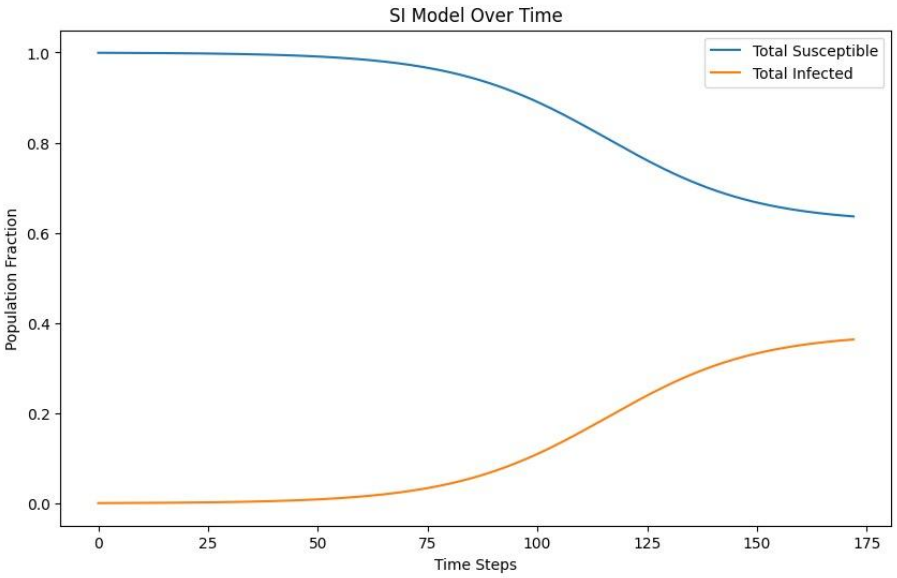
- **Weekly Epidemiological Snapshot**
  - COVID-19 figures across United States, YYYY-MM-DD format
- Comprehensive Data Aggregation
  - Collected new and cumulative confirmed cases, deaths, recoveries, and tests
- Calculating Infection and Recovery Rates
  - Utilized new cases and deaths data to determine infected and recovered population percentages for modeling
- Data Source and Reporting
  - from **CDC**
- Split into **80/20 training & validation sets**

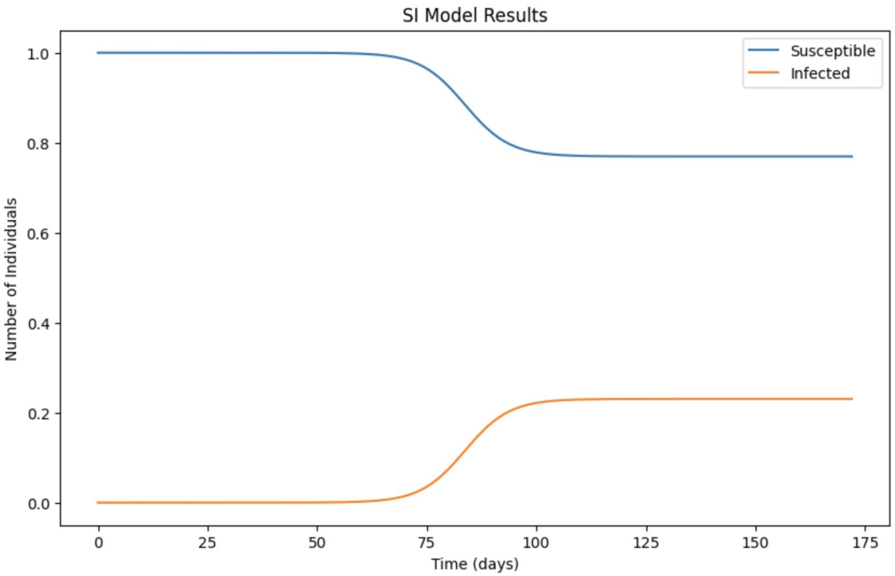
Experiments Overview

- Compare loss, normalized errors, and correlation coefficients to **determine which model combination simulates the COVID-19 data most accurately**
- Model Evaluation: weighted mean-squared-error (MSE)

	With LTM	Without LTM
SI Model	?	?
SIR Model	?	?
SIRS Model	?	?

Experiment - SI Model (LTM vs. non LTM)





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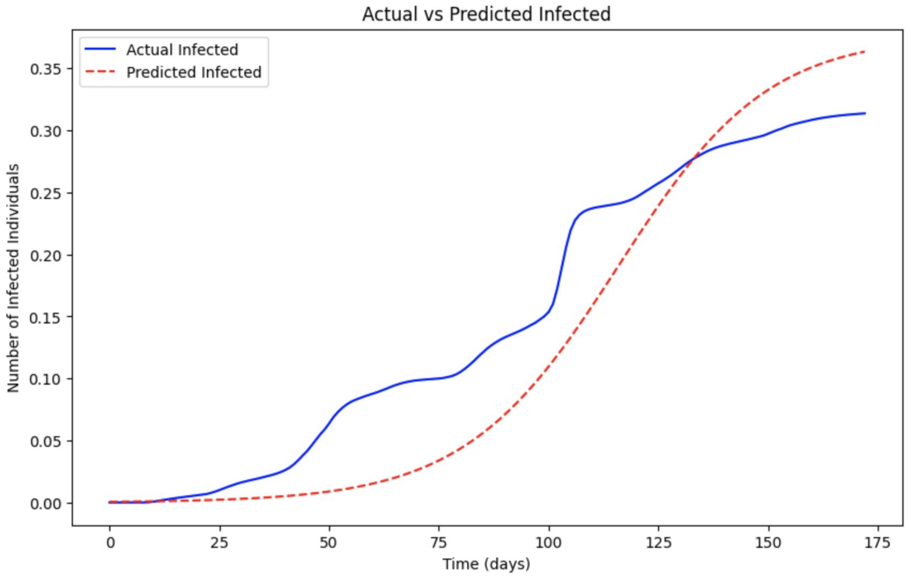
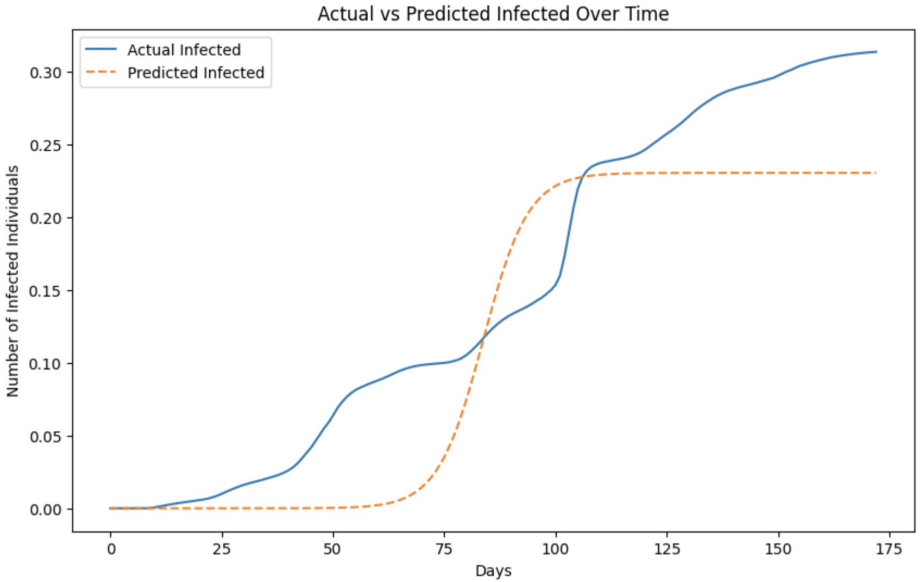
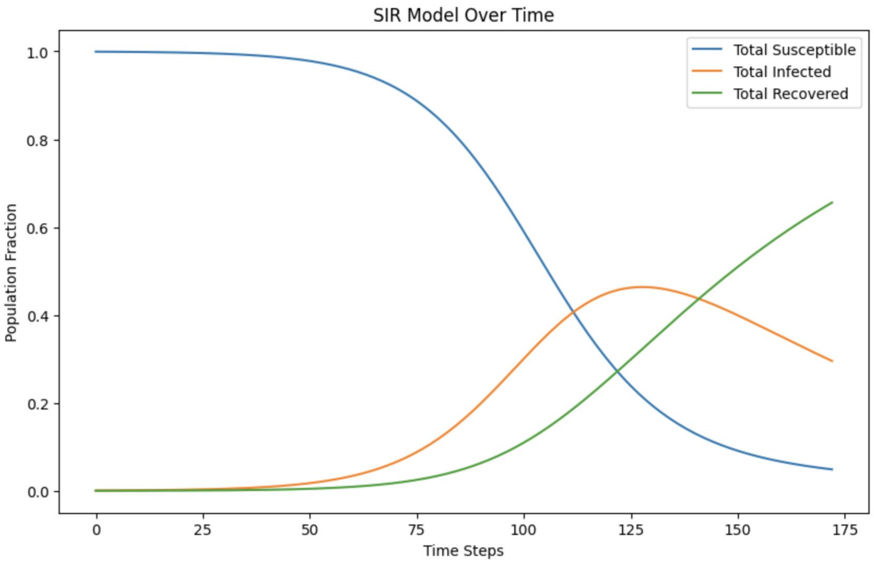
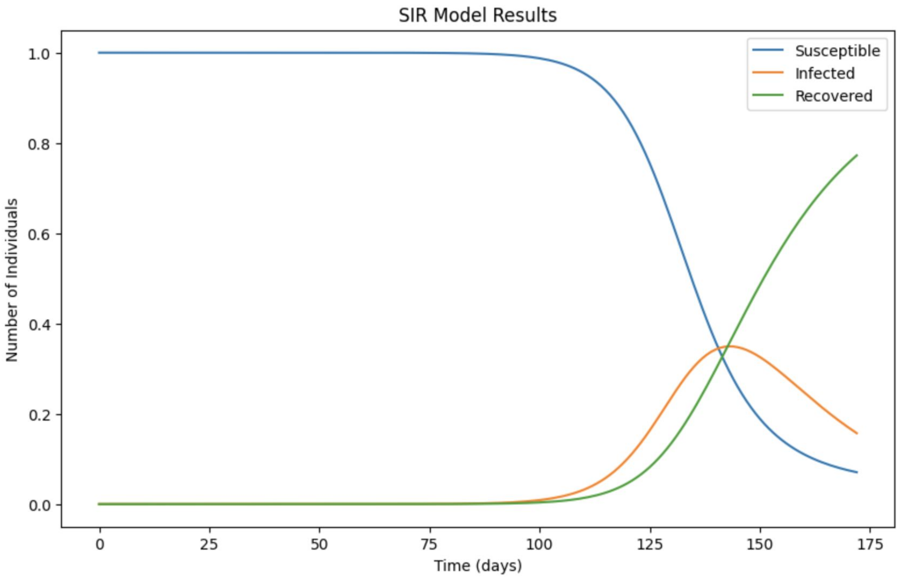
Experiment - SI Model (LTM vs. non LTM)





Experiment - SIR Model (LTM vs. non LTM)





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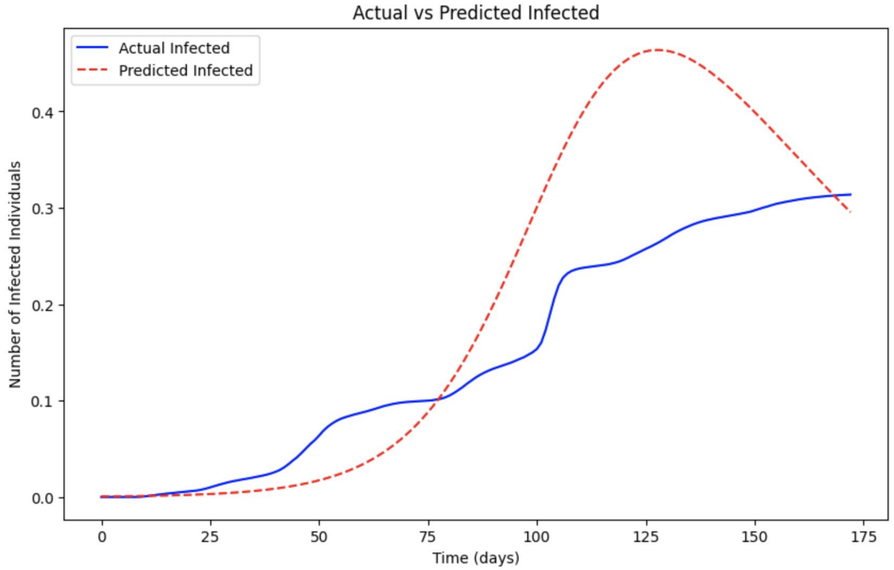
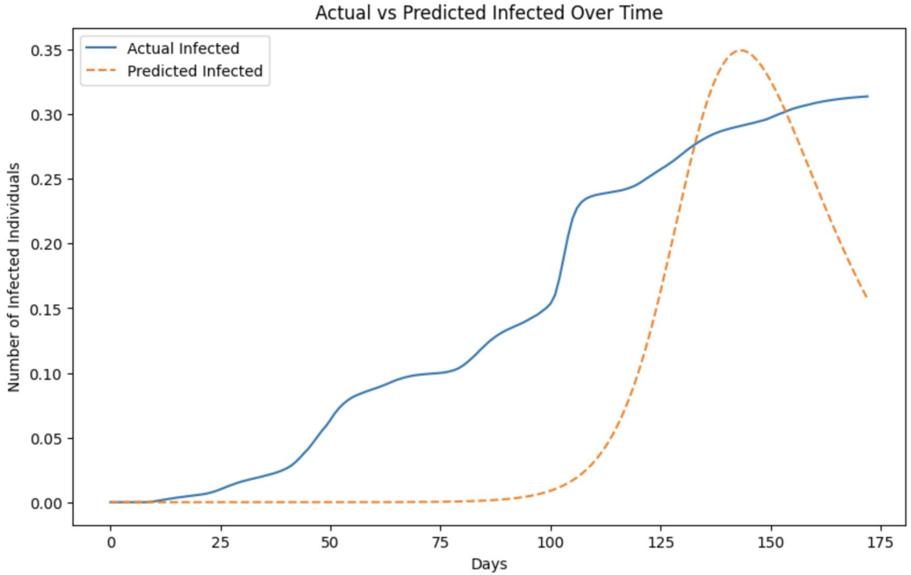
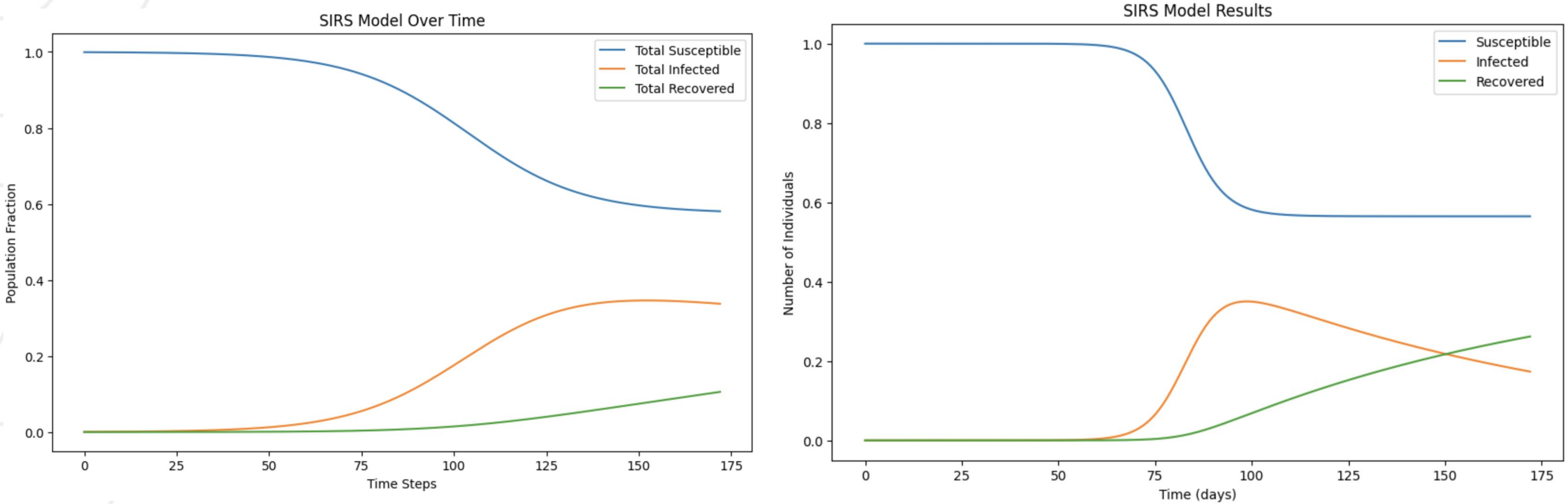
Experiment - SIR Model (LTM vs. non LTM)





Experiment - SIRS Model (LTM vs. non LTM)



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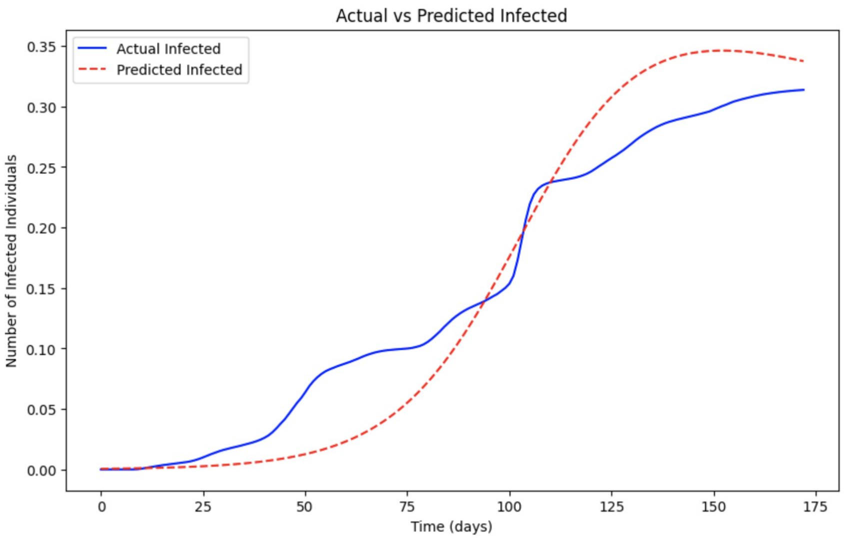
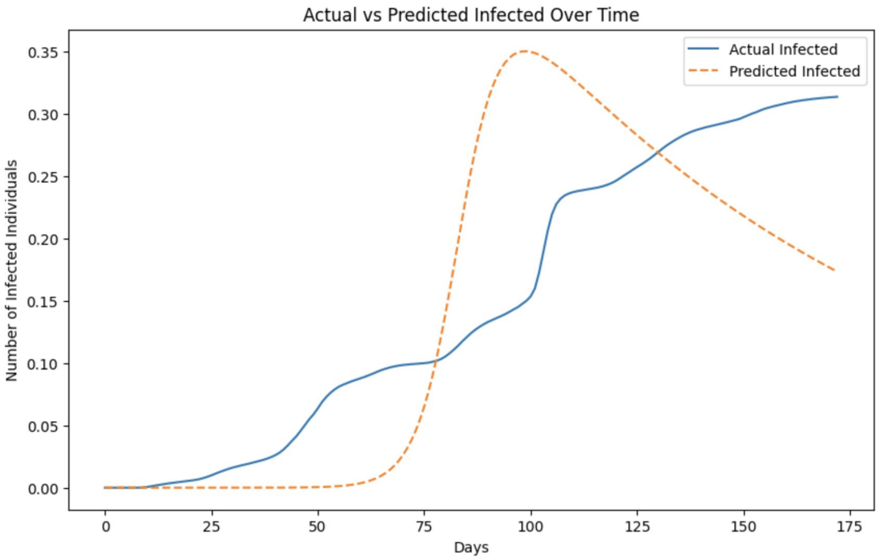
Experiment - SIRS Model (LTM vs. non LTM)





Best Results

- Validation **MSE scores** for various model combinations

	LTM	No LTM
SIR	0.0098	**0.0093**
SI	**0.00216**	0.0027
SIRS	**0.00138**	0.00757

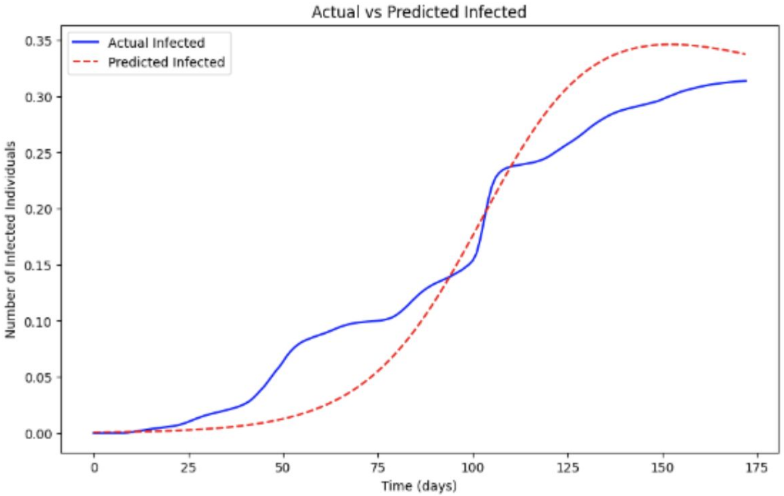


Figure 1: SIRS with LTM: actual infected population % v.s predicted infected population %. MSE = 0.00138

Conclusion

- Augmenting SIR model with real-world data can significantly increase accuracy
- LTM model which highlighted **mobility was an influential factor** predicting disease spread
- **LTM combined with SIRS model produced best results**

Future Work

- Incorporate an enhanced dataset to better capture mobility between states
    - Ex: likelihood of travel between states, # of flights between states
- Improve SIRS Model
    - add in a factor to delay re-infections due to immunity provided by a prior infection
- Including vaccination data to help gain insights on how and where vaccinations can be best deployed

Thank you!
Q & A