Project Report

On

An agent-based Model of Epidemic Spread and its Effect on the Economy

Topics in Applied AI -COMP 8790

Prepared by

Group 5

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1. INTRODUCTION

Epidemiological modelling, or simulating how a disease spreads through a community, can be done in a variety of ways. A system of coupled non-linear differential equations is used to represent the dynamics of the diseased population in the classic, well-known method of modelling the population and disease propagation.

The second type of epidemiological modelling involves using contemporary Network Theory techniques to represent an underlying social network and population interaction.

It is crucial to understand that two sets of factors influence how a disease spreads through a population: the characteristics of the disease (such as its duration of infection and incubation, the timing of its symptoms, and its infectious mechanisms), and the organization of the population's social network (contact rate, social clustering, and migration).

In any epidemic, the loss of people and rate of recovery is expected but predicting the effect on economy is difficult. So, the aim of our model is to simulate the speed of the epidemic spread and to find the state of the people and how this effects economy. We need to understand how an epidemic spread and how it impacts the economy so we can better prepare for it.

In this model, our agent is humans who are in one of the four states: healthy, suspected, infected, and recovered. We will consider these states and find the rate of health and recovery.

We are considering different factors, for example, infection rate, population density, isolation, etc. We will also consider the factors such as gender, location, age, and the number of people they met. With this information, we can find the rate of spread.
For finding economy we will use factors like Income per month, Shopping List, GDP…etc.

In this model we will try to mimic how people make decisions when they are infected with a disease and what impact that has on the economy.

2. LITERATURE REVIEW

2.1 Paper 1: Covasim: An agent-based model of COVID-19 dynamics and interventions

Models with the ability to forecast epidemic patterns, investigate possible interventions, and calculate resource requirements are urgently needed because of the COVID-19 pandemic. Here, the outline Covasim's (COVID-19 Agent-based Simulator) methodology, an open-source model created to assist in answering these queries. Covasim includes age-specific disease outcomes, intrahost viral dynamics, including viral-load-based transmissibility, realistic transmission networks in various social layers, including households, schools, workplaces, long-term care facilities, and communities. It also includes country-specific demographic data on population size and age structure. Additionally, Covasim supports a wide range of interventions, such as physical separation and protective gear, non-pharmaceutical interventions like vaccination, pharmaceutical interventions like isolation, contact tracing, and quarantine, and testing interventions like symptomatic and asymptomatic testing, isolation, and quarantine.[1]

2.2 Paper 2: Epidemic Spreading in Urban Areas Using Agent-Based Transportation Model

Jurgen Hackl et al proposed a large-scale agent-based model to simulate transport to study the seasonal influenza epidemic outbreak. They used the model to study the outbreak in Zurich, Switzerland, and showed a comparison with the SIR model. In their model, they have designed each agent as an individual to create a realistic representation of actual outbreak, each agent was directly assigned infection and recovery probabilities. Using simple assumptions, the model was able to produce good approximation of the historical epidemic breaks in 2016/2017. A key element in modelling realistic disease propagation model is the travelling of intelligent agents. As agents travel from one subpopulation to another, one group to another, the probability of an epidemic break increases. [2]

2.3 Paper 3: Agent Based Computational Epidemiological Modeling

The objective of these paper is to (i) comprehend baseline population behavior, (ii) quantify the effects on results of small changes in inputs (sensitivity studies) and of larger changes in inputs (parametric studies), (iii) identify the effects of various interventions, (iv) explicate behaviors and establish causality, and (v) comprehend results in terms of their policy implications. It is helpful to keep in mind that networks typically have 10s or 100s of millions or even billions of agents (nodes) and 100s of millions or billions of edges. Consequently, to compute quantities for many of this research efficiently, parallel processing is needed.[3]

2.4 Paper 4: Artificial Intelligence Applications in Tracking Health Behaviors During Disease Epidemics

Infectious disease outbreaks and resurgences continue to pose a serious threat to the health of the world's population, hence stronger pandemic preparedness measures are required to address these dangers. Artificial intelligence (AI) gives fresh promise for effectively anticipating, avoiding, and combating the hazards of infectious disease epidemics. It also makes it easier to understand the public's emotions and health-seeking activities during epidemics. With the help of targeted, context-specific interventions that encourage cost-savings on therapeutic care, increase access to health information and services, and foster increased individual responsibility for their health and wellbeing, AI offers enormous potential for public health practitioners and policymakers to transform healthcare and population health.[4]

2.5 Paper-5: Predicting the effects of COVID-19 related interventions in urban settings by combining activity-based modelling, agent-based simulation, and mobile phone data

This paper helps to better comprehend and forecast the transmission of infectious diseases, such as COVID-19 and epidemiological simulations that are employed as a strategy. In this study, a tried-and-true method for transportation modelling is combined with a mechanistic infection model and a person-centric illness progression model. The method leverages person-centric data-driven human mobility modelling.

The model can be used to comprehend how various activity types affect the dynamics of an infection over time. It can quantitatively forecast the effects of interventions by predicting the effects of reduced contact, school closures or holidays, masks, or the impact of shifting outdoor leisure activities to indoors[5]

2.6 Paper-6: Simulation Agent-Based Model to Demonstrate the Transmission of COVID-19 and Effectiveness of Different Public Health Strategies

Yixing et al demonstrated the transmission of COVID-19 in the ABM model they designed. Along with the transmission, the effectiveness of different public health strategies was simulated. While government administrations worldwide worked religiously to enforce protocols to decrease the spreading of COVID-19, the general public did not uniformly comply with the regulations. Thus, the authors developed an accessible tool to educate public about the viral transmission. They implemented the simulation using the game development engine Unity. There were three types of buildings: residential, offices, and hospitals. Each agent was given different health status from the set – healthy, infected, detected, and recovered. Agents had four simple moves possibility – left, right, up and down. To simulate the interaction between humans, the agents were able to collide with each other.[6]

3. MODEL DESCRIPTION

We plan to implement an agent-based model of epidemic spread and its effect on the economy. This model will help users make decisions on imposing customized health regulations for distinct groups of people.

In the model we plan to create hospitals, schools, colleges, corporate offices, residential apartment buildings, and intra-city transportation by collecting real life data, and structure of every establishment. We hypothesize that, every distinct group has an unique rhythm of daily life and activities. For example, in a hospital setting, people may need to use PPT, mask, and strictly maintain social distance to have the best shot at reducing the virus spread. But in a corporate office setting, people may stay at one place for greater length of a day, thus a lighter health regulation may be enough to keep the virus spread to a minimum.

If an economy is to survive, people must live their lives as close as possible to their normal pace of life. Adjusting the restrictions of public health regulations, accordingly, may provide the best possible chance at keeping the economy damage to a minimum.

The model will be made up of agents, which are connected to each other, and each agent has a set of rules that will determine how they interact with other agents. The model will be used to simulate the spread of the disease, and the effect of the disease on the economy, by running the model many times and observing how the agents interact with each other.

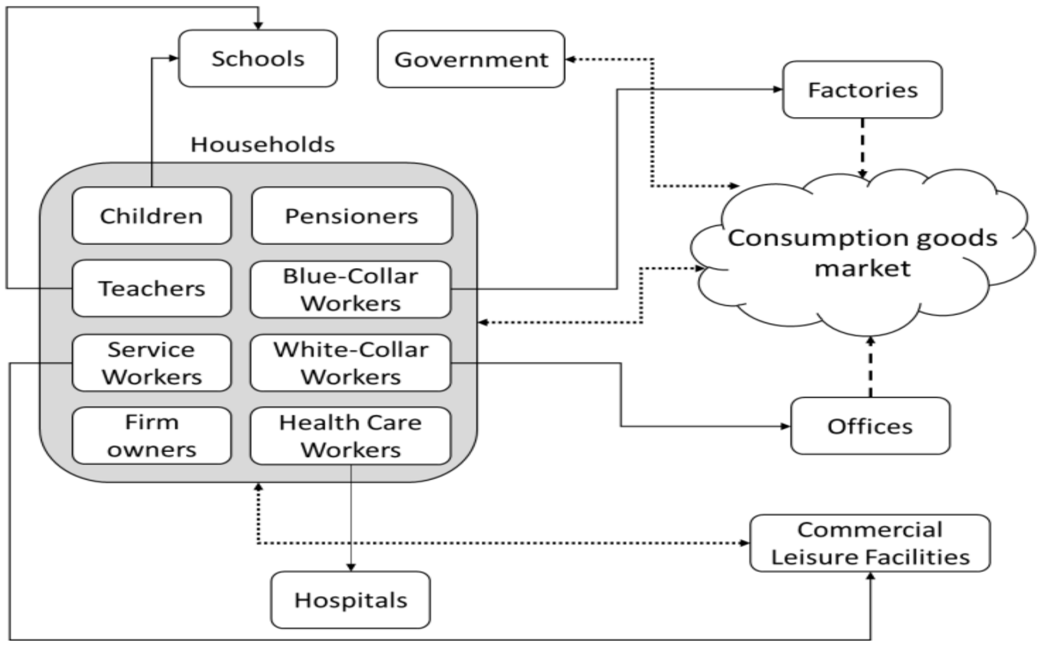


Figure 4: Depiction of the economy. Solid lines represent work relations, dashed lines production and dotted lines consumption. Factories, offices and commercial leisure facilities are owned by firm owners. Schools and hospitals are operated by the government.

Source: https://arxiv.org/ftp/arxiv/papers/2011/2011.06289.pdf [7]

3.1 Benefits of the model:

- We can use this model to understand the dynamic of an epidemic spread.
- From analyzing the data, we can predict the rate of spread as well.
- From the simulation result, we can deduce which combination of the health policies worked best to reduce the spread.
- Government and health authorities can use the suggested ABM as a beneficial tool to help them organize their actions to stop the economy damage as well as the spread.
- We can use this model to help users make decisions by providing them with information about the potential spread of an epidemic and its potential effect on the economy. This information can help users make informed decisions about how to best protect themselves and their businesses from the potential negative effects of an outbreak.
- Helps to reduce the economic damage by allowing the smooth flow of GDP and prevents recession

3.2 Agent Description

This agent-based model will consist of two types of agents: people and businesses. People will be represented by individual agents, and businesses will be represented by agent populations. Each agent will have a location and will move around the environment according to a set of rules. The rules for movement will be based on the agent's current state (e.g., healthy, infected, recovered, immune), the state of other agents in the environment, and the agent's proximity to other agents [8].

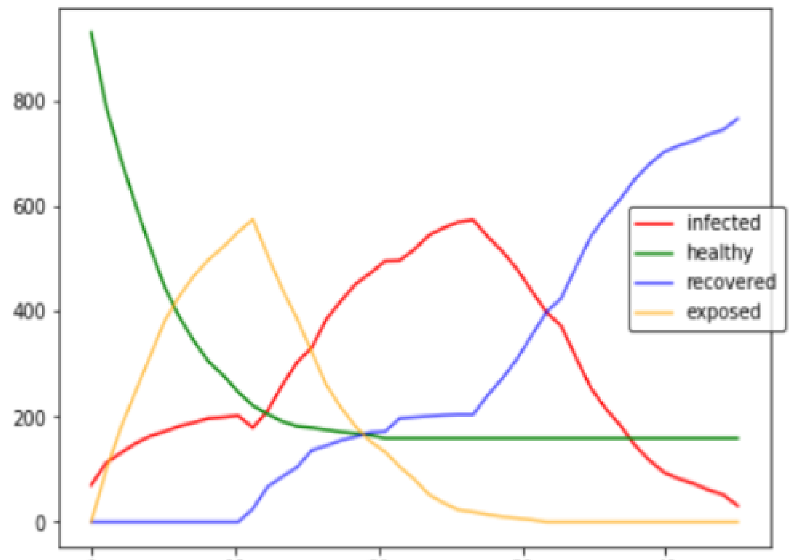
The model will include parameters for the rate of infection, the rate of recovery, the rate of immunity, the rate of death, and the rate of economic impact. Parameters like Type: Business Owners, Buyers, Income per month, Shopping List: Each item will be given priority.

These parameters will be varied in order to probe the effects of different epidemic scenarios on the economy.

3.3 Life of the agent:

- Susceptible -> Came in contact with infected agent -> Incubation period -> Infected -> Recovery/Death

The life of the agent is as follows: each step in the simulation is one day. The agent starts the day by being in one of four states: susceptible, infected, recovered, or dead. If the agent is susceptible and meets an infected agent, there is a chance that the susceptible agent will become infected. If the agent is infected, there is a chance that the agent will recover or die. If the agent recovers, the agent becomes immune to the disease.[9]



3.4 Parameters to probe

- Number of - Susceptible, Exposed, Infected, and Recovered agents: Use a system of differential equations to model the spread of the pandemic.
- Mortality and Recovery rate: Use data from previous pandemics to estimate the mortality and recovery rates.
- The rate of the spread vs the economic flow: Use data from previous pandemics to estimate the rate of the spread of the pandemic and compare it to the economic flow.
- Total GDP: Use data from the World Bank to estimate the total GDP.

The pandemic is spreading at an exponential rate. The number of new cases is doubling every few days. The virus is spreading through the population very quickly and is now present in almost every country in the world. The death toll is rising rapidly and the number of people who are seriously ill is also increasing. The healthcare systems in many countries are struggling to cope with the influx of patients and are running out of supplies.

Mortality refers to the number of deaths in a population, while recovery rate refers to the number of individuals who recover from a disease. The two measures are important in determining the health of a population. A high mortality rate indicates many deaths, and a low recovery rate indicates a small number of individuals who recover from a disease.

3.5 Implementation

The model will be set up such that we can run experiments with different values for the parameters and observe the results. We will use Python libraries for agent-based modelling, such as Mesa, to implement the model.

To set up this project we will use a dataset containing gender, location, number of people a person contacted, age and wealth, etc.

We can use the python libraries matplotlib, ipywidgets and numpy in jupyter notebook to implement the model.

4. CONCLUSION

The agent-based model of epidemic spread and its effect on the economy has the potential to be a useful tool for understanding how epidemics can affect economic activity. The model will also be able to capture the key mechanisms by which an epidemic can reduce economic activity, such as through the death of workers, the reduction in productivity of workers who are ill, and the decrease in consumer confidence. The model is also able to capture the potential for an epidemic to have a multiplier effect on the economy, as the reduced economic activity can lead to further job losses and reduced consumer spending. The model will produce a combination of effective public health regulations aimed towards unique needs to different social groups.

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