Improving the handling of COVID-19 in New York City hospitals

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Abstract*-- Over the past year, health care systems faced ever-increasing pressures due the worldwide phenomenon, COVID-19 or Corona virus pandemic. Discrete Event Simulation has become a popular and effective decision-making tool for the optimal allocation of scarce health care resources to improve patient flow while minimizing the health care costs and increasing patient satisfaction. This paper provides a summary of the article which explains the potential of using discrete event simulations to improve the handling of COVID-19 or corona virus patients in hospitals in New York City.

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Keywords—Discrete event simulation, Corona Virus, Demographic data, Hospitals

I. INRODUCTION

This is a summary on the article "New York City Hospital Simulation Modelling" by Allan Lu. The article focuses on how to improve the handling of COVID-19 in New York city hospitals using discrete event simulation methods. According to the author, the project initially started as a means to explore the epidemiology of the COVID-19 pandemic in New York City. Data was gathered from the daily summaries released from the city's Department of Health from March. Once the data was gathered, he saw the potential to use this accumulated data to examine the city's capability in handling the current COVID-19 pandemic situation. He also used Discrete Event Simulation methods to simulate and check how can they respond. Discrete Event Simulation is an Operations Research modelling and analysis methodology that permits end users (such as hospital administrators) to evaluate the efficiency of existing health care delivery systems and to design new health care delivery systems operations. Discrete-event simulation can also be used as a forecasting tool to assess the potential impact of changes on patient flow.

II. MOTIVATION

Corona virus or COVID-19 virus has a major catastrophe to the whole world. It has led to dramatic loss of human life and presents an unprecedented challenge to public health, food systems and the world of work. The economic and social disruption caused by the pandemic is devastating. There are so many fields which are getting destroyed due to this pandemic and the livelihood of many people is being affected. For our term paper, we would like to choose one of the areas which need to be improved in order to tackle the COVID-19 or corona virus pandemic better. Our chosen area is the handling of patients in hospitals. Since better handling of patients directly means that a greater number of people are getting treated, it will be an important thing to improve upon. This was done using Discrete Event Simulation of the hospitals in New York City.

III. LITERATURE REVIEW

A. Simulation modelling of patient flow and

This paper portrays research including the improvement of a recreation model of the patient stream to comprehend the connection among limit and request, and to explore the effects on execution estimates, for example, Average wait times for LTC patients. We propose a total limit model to think about patient stream among different kinds of care suppliers by coordinating clinics, nursing homes, assisted living offices, and home medical care.

Long haul Care (LTC) incorporates various kinds of care administrations to meet clinical and non-clinical requirements of individuals who experience issues really focusing on themselves for delayed timeframes because of constant infection or incapacity. While most LTC is available to individuals of all ages, it is a more normal need among maturing populaces.

The requirement for LTC emerges generally in the older populace with persistent infection or inability, whereby causing constraints from exercises of everyday living (ADLs, for example, strolling and eating to instrumental exercises of day by day living (IADLs, for example, driving and shopping. LTC administrations can be given in an assortment of settings including homes, grown-up childcare places, private/network care offices, helped living offices, and nursing homes. At the point when a genuine sickness happens or family guardians are not, at this point accessible to give help, free living may presently don't be suitable, provoking numerous patients to require changes in their living courses of action by looking for help for individual consideration and falling back on nursing homes and helped living offices.

Persistent information were investigated in four gatherings by sex and age to gauge interest and LOS for every patient class. In this part, we portray the strategies utilized for estimating understanding interest just as for fitting inspecting conveyances to LOS information.

B. *Discrete Event Simulation-Based Approach for Hospital Services Development and Monitoring*

A discrete occasion reproduction model can portray measures, even perplexing, where the elements that administer the measure (characterized components or elements) are reliant with each other and work together to accomplish a typical objective. The portrayal of the framework permits, subsequently, a point by point examination of the presentation of the general framework in terms of speed, limit and count.

The utilization of reproduction in clinical cycles permitted a right utilization of the accessible assets and enhanced the holding up time, so as to lessen, beyond what many would consider possible, the length of lines. The primary presentation markers investigated by the models are the 'hanging tight occasions' for getting an administration, the number of patients utilize the administration and what amount of time the patient requires to finish the test. This permits to re-enact reality for extensive stretches, monetarily and on the cycle seen by recognizing bottlenecks to allot assets in the most ideal manner.

The model was worked by precisely contemplating the booking, registration, paying and results get embraced by the clinical research facility administrations of the Careggi Teaching Hospital. As per the logical writing, to appropriately reproduce the activity of the cycle is important to know the quantity of patients showing up to the front work areas, the normal time of administration for registration and test get. Additionally, to approve the right activity of the model, we need the authentic information identified with holding up occasions of patients. These information were acquired through direct perception, interviews with staff and getting to clinic information bases.

C. *Modelling for the planning and management of bed capacities in hospitals*

The inward elements of a medical clinic speak to a complex non-straight structure. Arranging and the board of bed limits should be assessed inside a climate of vulnerability, inconstancy and restricted assets. A typical methodology is to design what's more, oversee limits dependent on straightforward deterministic bookkeeping page figurings. This paper shows that these computations commonly don't give the proper data and result in belittling genuine bed prerequisites. More refined, adaptable and essentially itemized limit models are required. The turn of events and utilization of such a reproduction model is introduced in this paper.

Advances in medicines, a maturing populace, expanded, quiet assumptions and restricted assets are a portion of the factors that have expanded the pressing factors on emergency clinics. The arrangement of satisfactory quantities of beds, while making proficient and powerful utilization of those accessible, is of key worry for emergency clinics. In a climate of vulnerability furthermore, changeability, proper data for choice making is an extraordinary assistance. The interior elements of an emergency clinic speak to a complex non-direct structure. To design and deal with these assets requires a decent comprehension of the clinic framework. This paper exhibits how scope organization dependent on a usually received basic deterministic methodology will generally bring about deluding results, regularly belittling emergency clinic prerequisites. Moreover, they overlook the complex connection between bed inhabitancy and denied confirmation rates. Scope organization alternatives should be investigated in light of such calculation.

IV. ACQUIRING THE DATA

The NYC Department of Health releases their COVID-19 data at two geographic resolutions, by borough and by zip code. Borough is an administrative division within a city. New York City is divided into five boroughs. The borough data is too coarse to derive any useful spatial information for such a small study area. Therefore, we will be using their zip code data for this project. All of the datasets, besides the COVID-19 one, are accessed directly online through an API or a URL.

A. *Census Demographic Data*

Start by downloading the demographic information into a **Pandas** Data Frame. The following code uses the 2010 census data and aggregates the census blocks into zip codes. The 2010 census data is accessed using their API with an API key. To run the code below, acquire an API key here. Set the `api_key` variable to the census API key they provide as a string.

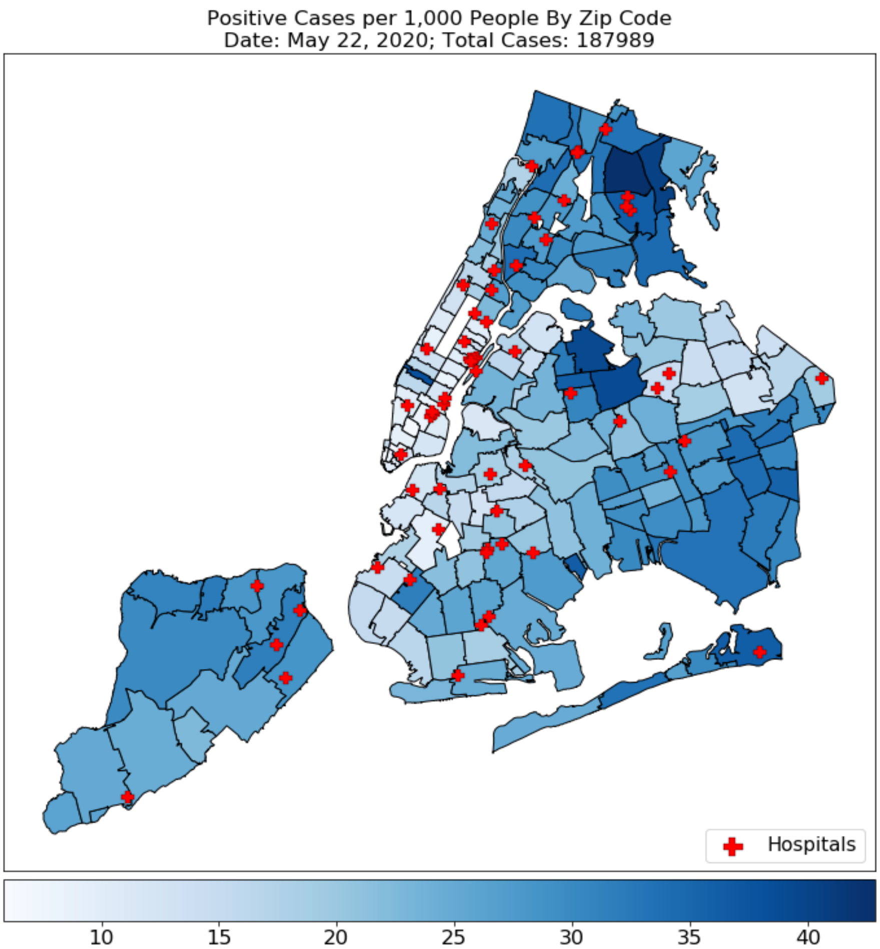
From the 2010 census, download the demographic variables to ZCTA levels for rage, gender and age. The following chunk of code takes some time to run since it runs two nested loops to create the demographics table.

Using the modified ZCTA data from NYC Health, aggregate the census data to the MODZCTA's and calculate the percentages of each demographic variable. Modified ZCTA combines census blocks with smaller populations to allow more stable estimates of population size for rate calculation (Fig-1).

B. *New York City hospitals data*

Finally, download the NYC hospitals point data to a GeoDataFrame. The NYU dataset includes hospital capacity which will be used in the discrete event simulation.

Fig-1: Choropleth map



V. EXPLORATORY DATA ANALYSIS

A good idea before performing any statistical analysis or modelling is to explore the you have. For spatial data, the best way is to map them out as vectors or rasters. We will be using the **matplotlib** package to visualize the relationship between COVID-19 data and hospital location.

A. COVID-19 Choropleth map

A choropleth map is a type of thematic map in which a set of pre-defined areas is colored or patterned in proportion to a statistical variable that represents an aggregate summary of a geographic characteristic within each area.

Above is a choropleth map (Fig-1) showing the current total number of confirmed positive cases in NYC by ZCTA, with a hospital point layer.

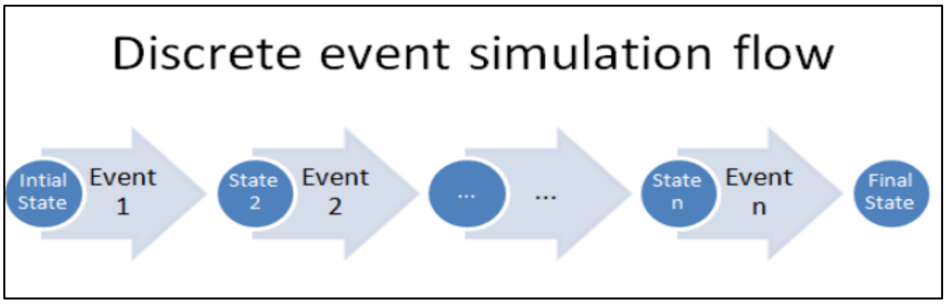
VI. DISCRETE EVENT SIMULATION

Discrete event simulation (DES) is used to model the operation of a system as a sequence of events and states in time. The events are recreated so that the system's timing and resource implications can be examined. DES operates under the assumption that these events occur instantaneously at discrete points in time. After each event, the entity is in a new state. It has been used for many years to improve workflows and services.

For example, imagine a supermarket with 6 cash registers and a queue of customers. In this system (the supermarket checkout) the registers are the resources, and the customers are the entities. The 3 basic events that occur are:

1. a customer gets in line.
2. a customer is rung up at the register.
3. they leave the supermarket.

Although each event is discrete, the duration from when one occurs until the next is not. This span of time is measured in a discrete event simulation to assess how well the system can allocate resources efficiently. In this project, we will be modelling how well New York City hospitals can manage the COVID-19 crisis. Here, the basic events are:



1. a patient's arrival at a hospital
2. if a bed is available, they are admitted or
3. if no beds are available, they are turned away.
4. a patient is discharged from the hospital.

The image below shows a simple DES workflow.

This project uses the discrete event simulation Python package, **SimPy**. **SimPy** uses Python generator functions, called processes that create events and yields them in order to wait for them to be activated.

A. Hospital service area calculation

The first thing to be done before creating the simulation is to calculate the service area of each hospital in New York City. To do this, we are using the nearest neighbor analysis between the hospitals points from `hospitals_geom` and the ZCTA centroids in `zcta_gdf`.

We will find the nearest hospital to each ZCTA, and then the service area of each hospital. This is done by grouping the data frame returned from the `nearest_neighbor` function by the unique hospital ID and totalling the values in each group.

The average daily new COVID-19 cases are calculated for each hospital by averaging the difference between consecutive columns for the 30 days from April 3rd to May 3rd. Everything is gathered together into a `hospitals_gdf` GeoDataFrame.

B. Simulation Setup

With the `hospitals_gdf` set up, we can start creating the discrete event simulation. The code below creates the system and processes needed for the simulation. A Hospital class is created for the system being simulated, containing a limited capacity of resources, beds. The patient process function simulates a patient arriving at, being admitted, and being released from a hospital.

C. Run Simulation

Now that the system and process are defined, we will set up and start the simulation. The code below iterates through each hospital in the hospitals_gdf GeoDataFrame:

- creates a **SimPy** environment for that hospital
- sets up the variables for the simulation
- runs the simulation
- creates a **Pandas** Data Frame that tracks the number of patients admitted, released, and refused in that hospital.

The simulation is run for 60 days. The number of starting patients uses the occupancy rate percentages from the American Hospital Directory. The percentage of patients that are admitted to a hospital due to COVID-19 is from the CDC.

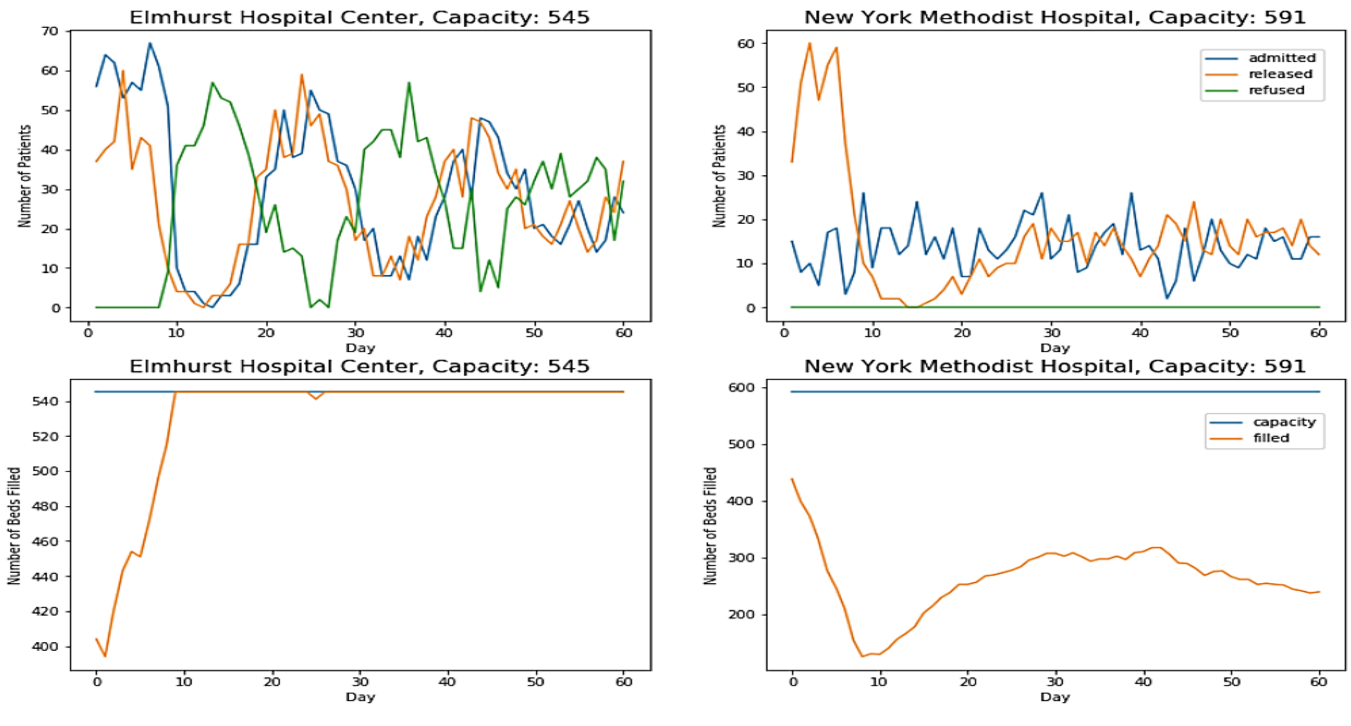


Fig-2 : Comparison graphs

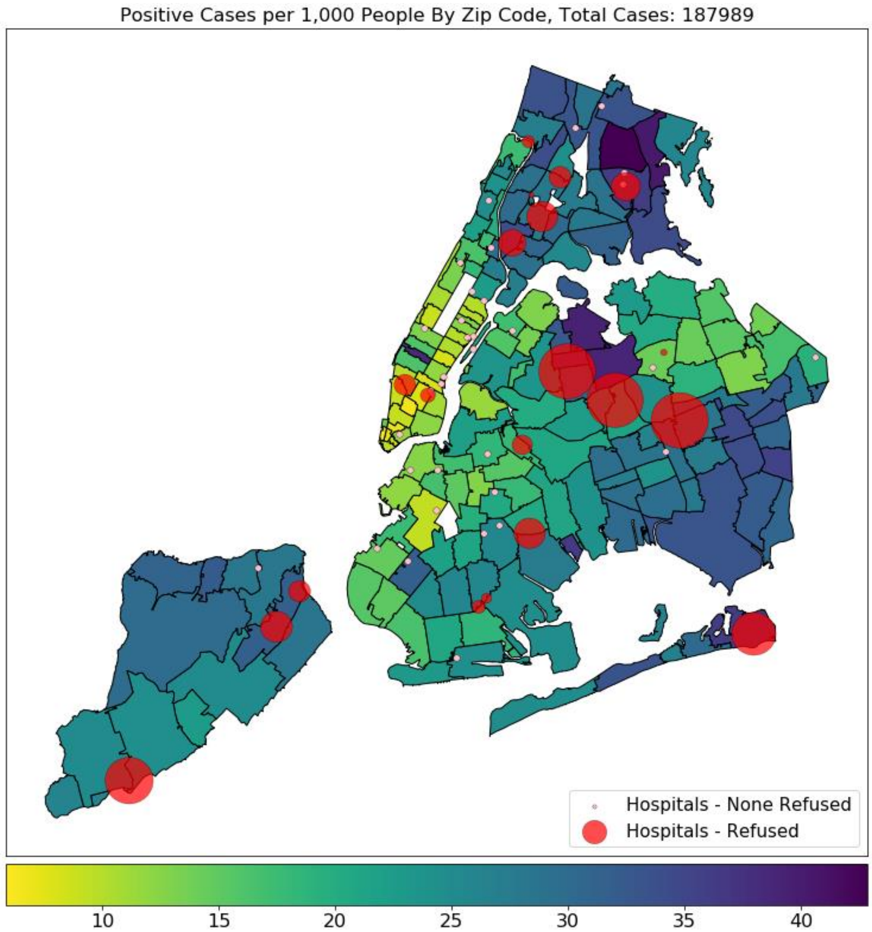


Fig-3: Static map

VII. RESULTS

A. Comparision Graphs (Fig-2)

The simulation created around 55 data frames tracking the number of patients admitted, released and refused at each hospital. Let's explore two of these tables. We will compare the results from Elmhurst Hospital in Elmhurst, Queens and New York-Presbyterian Brooklyn Methodist Hospital in Park Slope, Brooklyn. Both hospitals have the about the same number of beds, however, Elmhurst Hospital covers a larger service area with more new cases each day. Therefore, Elmhurst Hospital simply does not have enough resources to accommodate the higher demand.

B. Static Map (Fig-3)

After exploring a sample of the simulation results, let's map everything out to see how many patients were admitted, released, and refused from all the hospitals. To start, we must add the sum of these values for each hospital in the `sim_dict` to the `hospital_sim` GeoDataFrame as three new columns. With the simulation results all in one GeoDataFrame `hosp_sim_gdf`, let's plot the data onto a static map. In the map below, the hospitals are plotted as circles with the number of patients refused at a hospital to representing the size of each circle. Hospitals that did not refuse any patients are smaller pink circles.

VIII.CONCLUSION

The COVID-19 crisis in New York City has had a tremendous impact on the city. As of May 23, 2020, there have been 194,667 reported cases, 51,117 hospitalizations and 16,403 confirmed deaths. This virus has completely changed the lives of the 8 million residents in this city, and many more. Hospitals have been working nonstop to treat the tens of thousands of residents, but with so few beds many have been and will be turned away. What will happen to those who get turned away? What happens if they die because they didn't get treatment? A hospital can only do so much with what they have. The purpose of this project was to analyze the performances of NYC hospitals using geographic information science and discrete event simulation. We were able to find the hospitals that might have problems handling the crisis.

The number of new cases each day has been decreasing in New York. For the future, we should calculate another `newdailycases` value using more recent data too see how the hospitals will perform with these lower numbers. Also, the discrete event simulation in this project was simplified and does not account for people acquiring and succumbing to the virus. We can add those two events to expand the simulation through all the stages of the illness.

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