Planes, Trains, and Afflictions

Agent-based modeling for the spread of disease through transportation networks

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Motivation

Why were certain areas of NYC more affected by COVID-19?
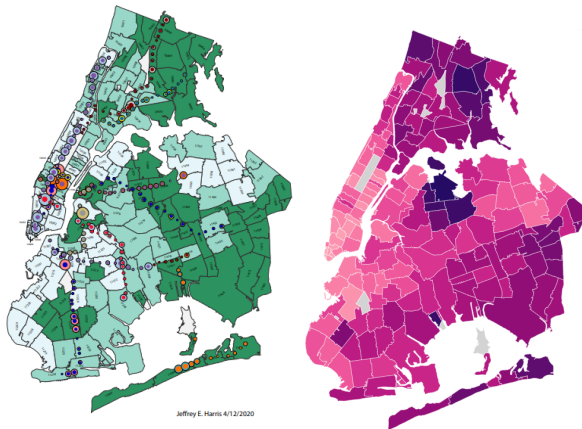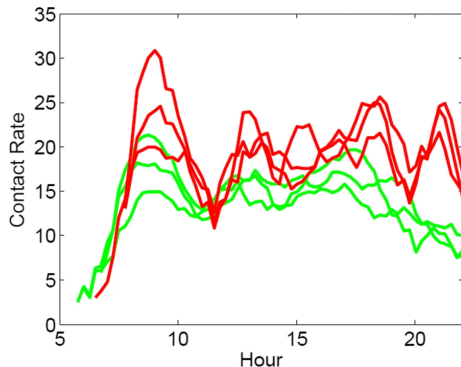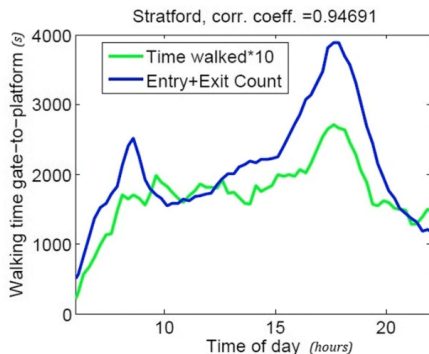How were the subways involved?

Figure: Left: Case Rate And Subway On April 12, 2020 [**?**]
Right: NYC COVID Case Rate As Of June 23, 2020 [**?**]

Prior Research (London Underground)

Data: Oyster (Card), CASA (Timetable), PHE Data (Demographics)

Results show a correlation between the use of the underground and ILI cases in London, specifically they show that higher numbers of ILI cases arise in those boroughs where the population spend more time in the Underground and/or incur in a higher number of contacts when travelling. [?]

COVID in London

Covid-19 Cases by London Borough (2020-03-23 to 2020-06-21)
Displaying cumulative count (all historic) at: 2020-06-21
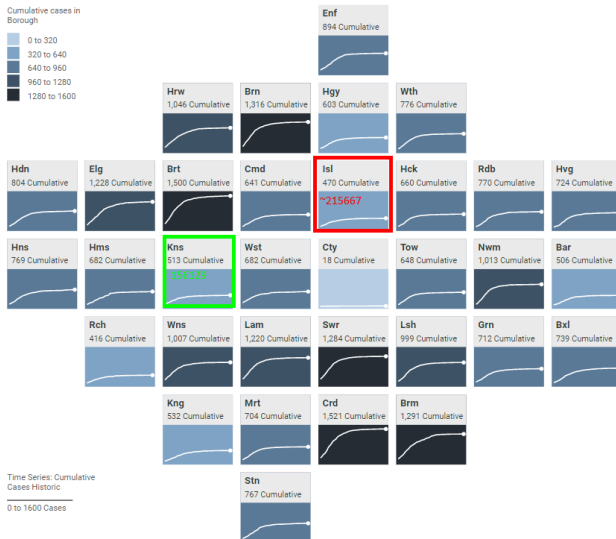
Source: https://coronavirus.data.gov.uk/ - Note: Data for most recent 5 days may be incomplete.
Graphic by GLA City Intelligence | London Squared Format by After The Flood

Speaker's Remark:
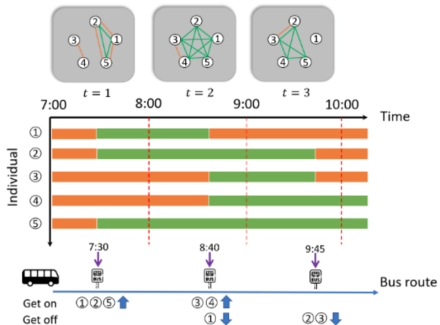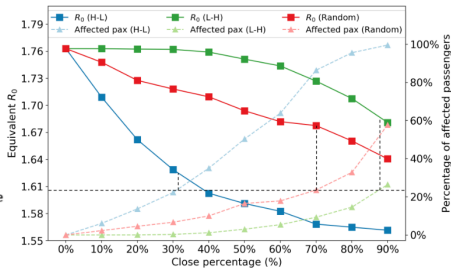
Prior Research (Singapore Buses)


Figure 1: Network representation of a five-passenger system

The direct contact in trains is, however, difficult to obtain from smart card data because the transactions are recorded at the station level [**?**]
Speaker's note:
- We show these things not to embarrass ourselves, but the depth of research available even just looking at one system. - List some other research
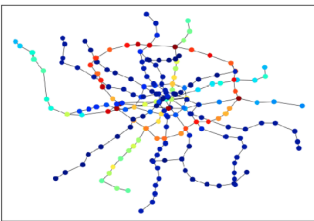
ABM Framework
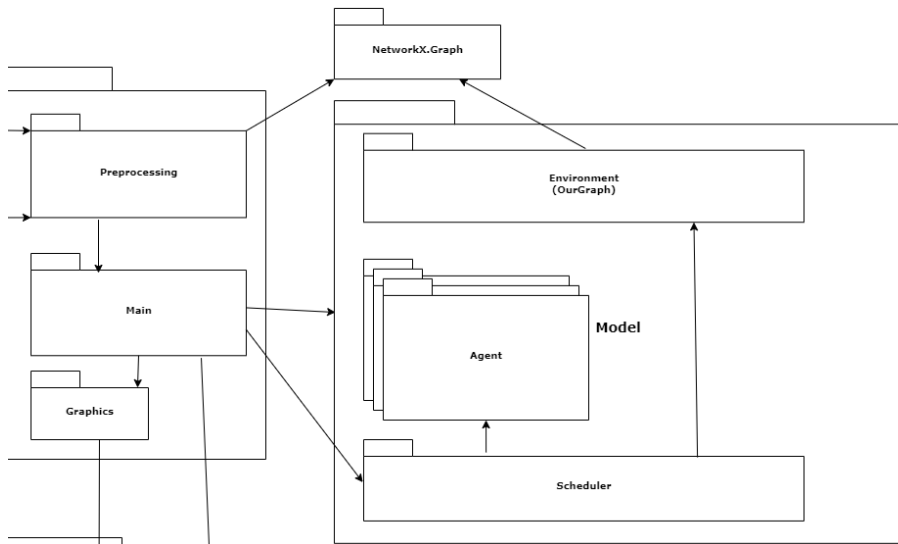
Components: Python, MESA, Networkx
Base Classes: Transportation Model, SEIR Agent

Simple Geometries
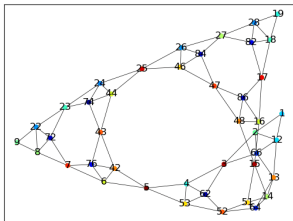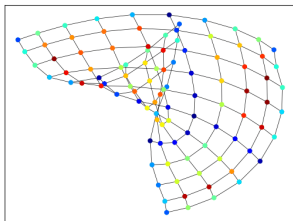
- Grid
- Sierpinski's Triangle
- Moscow

World Airline Network (Passenger Flow) - Challenges

Obtaining accurate data bout world passenger flow is a bit of callenge, one has 3 options:

1. Pay for it
2. Using superior math to extrapolate or estimate
3. Extrapolate based on what I know; We obted for option 3

Algorithm 1 to estimate WAN (Passenger Flow)

1. Find total number of passengers going through a specific airport
2. Total number of destinations from said airport
3. Ratio of traffic from each airport
4. Split population of passengers into various destinations based on ratio

Major challenge with this is the fact that we need to find data to answer each of these questions in order to make an estimate (ratios data)

Algorithm 2 to estimate WAN (Passenger Flow)

Using Data from Wikipedia and Openflights

1. Get the total population of data passengers that go through a specific airport.
2. Using HITS algorithm on airport pairs.
3. Split population of passengers into various destinations based on hubs obtained from HITS

Major challenge with this is the fact that the graph is undirected hence the HITS results were unreliable. Also if the data was split into major known hubs the data returned the same value from HITS.

World Airline Network (Passenger Flow) Algorithm
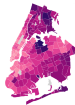
Madrid Commuter Trains (Central Hubs)

How important are central transportation hubs to disease spread? Data Source (madrid renfe gtfs)

Madrid Commuter Trains (Central Hubs)

Methods (ABM)

Results (Madrid)

NYC Demographics And COVID Timeline

NYC residents working in Manhattan primarily travel by subway. This is also true for residents of the Bronx, Brooklyn, and Queens [?]

- March 9 - Mayor holds press conference and notes that there have been 16 confirmed cases. (106 cases)
- March 12 - Mayor declares a local state of emergency. (687 cases)
- March 15 - Schools officially close. (2,986 cases)

Borough - A geographical region. NYC has 5 boroughs.

MODZCTA - Modified Zip Code Tabulation Areas. $\propto$ postal codes.

Subway Systems
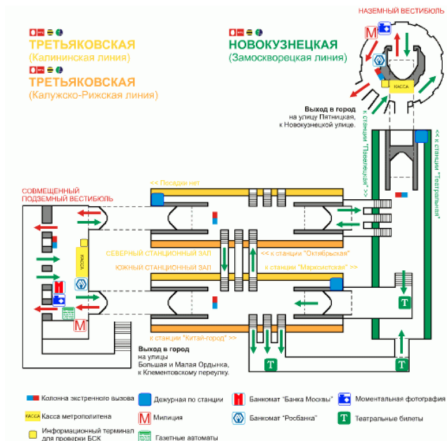
Complex, Station, Line, Route

Figure: Floor Plan of Novokuznetskaya Metro Station [?]

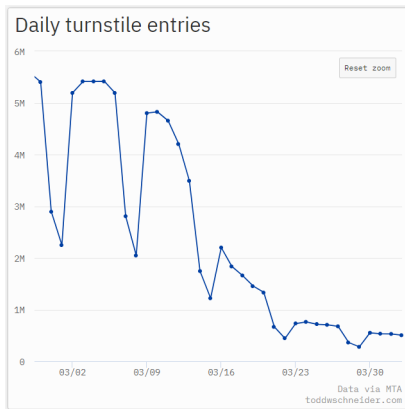# NYC Subway Data

Stations, Map, Turnstiles (GTFS not considered)

Figure: NYC Subway daily turnstile entries for March 2020 [**?**]

```
167,167,A32,IND,8th Av - Fulton St,W 4 St,M,A C E...
167,167,D20,IND,6th Av - Culver,W 4 St,M,B D F M...
```

NYC Subway Modeling

Algorithm 1 Simulation of Disease Spread on Subways

1: **for** $i = 1; i < TIMESPAN; i + +$ **do**
2:     Check conditions (i, number of infected) to see if we should deploy COUNTERMEASURES
3:     **for** Station in SubwayModel.Environment.Nodes **do**
4:         Calculate 'Local Exposure' from infected and commute time.
5:         Calculate 'Route Exposure' from infected on the same route.
6:         Calculate 'General Exposure' due to city-wide infected.
7:         Update 'Exposure' at station based on above conditions
8:     **end for**
9:     **for** Agent in SubwayNetwork.Agents **do**
10:         Get 'Exposure' At Location
11:         Get City-wide COUNTERMEASURES
12:         Get Percentage of commuters
13:         Calculate SEIR beta and gamma based on conditions
14:         Update SEIR numbers
15:     **end for**
16: **end for**

Subway Agent - SEIR Agent with additional exposure based on location.
Subway Graph - Nodes $\propto$ Stations, Edges $\propto$ **Lines, Complex**, Route Lookup.

NYC Model Parameters, Hyper-parameters

Default SEIR Rates: $\beta, \alpha, \gamma = 1.75, 0.20, 0.50$
Countermeasures: Isolation, Recommendation, Awareness: = 5000, 500, 500
Defiance: 10% Local, 25% Global
Global Exposure: 0.7
Commute Time: Squared shortest path from Grand Central or Times Square
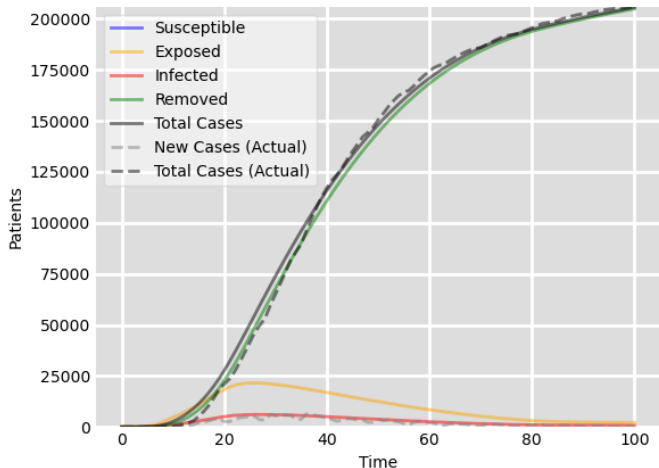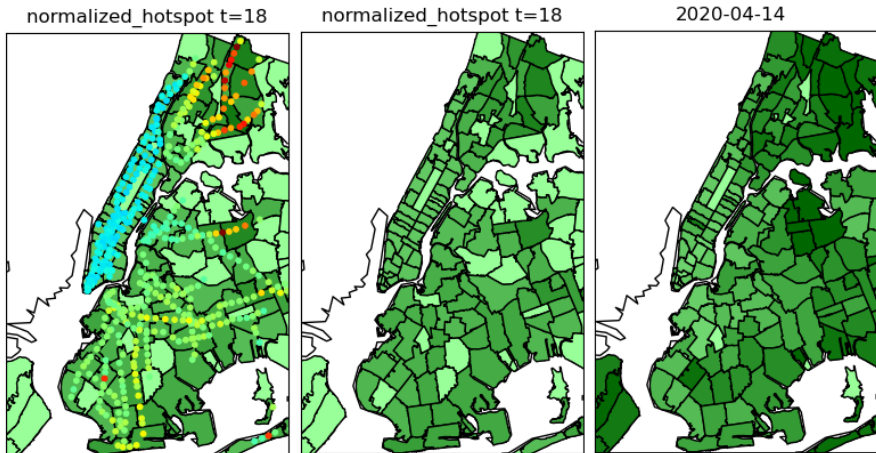
Compartmental Modeling Results (NYC)

Figure: SEIR Fitting to NYC Case Total. *MAPE (t ≥ 30): 0.0145*

Results by MODZCTA (NYC)

normalized_hotspot t=18   normalized_hotspot t=18   2020-04-14

New York City Timelapse

Discussion

All models are wrong!

- Passenger Flow
- Outer suburbs phenomenon exists
- Simple GDP/capita data
- Erase some of these stupid parameters

Conclusions

- Determining passenger flow is a difficult problem for all transportation networks at all granularities.

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Credits, Links, References

Frank Acquaye - WAN, Passenger Flow
Ho Lum Cheung - NYC, Organization, Research, Testing
Dimas Muñoz-Montesinos - Madrid, Hotspots
Elie Wanko - Theory, Consulting
github link references used in slides