Group 3 Project 4

Healthcare Accessibility - ABM

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1 Introduction

The goal of this project is to investigate the accessibility of healthcare facilities for elderly people in San Francisco by employing Agent-Based Modeling (ABMs) through NetLogo. Building upon the ideas and methods from Project 3, we aim to provide a more comprehensive analysis of healthcare accessibility for the elderly population by leveraging the advantages of ABMs. This project aims to provide valuable insights into the healthcare accessibility landscape for the elderly population and help inform future planning and decision-making processes to improve healthcare access for this demographic.

Agent-Based Modeling (ABM) is a computational modeling paradigm that focuses on simulating the behaviors and interactions of autonomous agents within a given environment. ABMs are particularly useful in understanding complex systems where the behavior of individual agents influences the overall system behavior. By modeling and analyzing the interactions of individual agents, ABMs can provide insights into the emergent phenomena and properties of the system that may not be apparent when considering only aggregated data.

In the context of our project, the ABM will simulate the behavior of potential elderly patients and healthcare facilities in San Francisco. The model will consider factors such as patient demand, facility capacity, appointment timings, and geographical distribution. The utility of our model lies in its ability to provide a more nuanced understanding of healthcare accessibility for the elderly population, considering various factors that can influence the overall access to healthcare services. This information can be used by policymakers and healthcare providers to make more informed decisions about resource allocation, facility placement, and service provision, ultimately improving the accessibility of healthcare for elderly residents in San Francisco.

By using the ABM approach, our project will calculate accessibility scores for each census block and create a healthcare facility accessibility map for San Francisco. This map will provide a visual representation of healthcare accessibility levels across the city, highlighting areas with higher or lower access to healthcare facilities for the elderly population. The findings of this project have the potential to inform future planning and decision-making processes, contributing to the development of more equitable and accessible healthcare systems for elderly residents in San Francisco.

2 Spatial Data

The datasets used in this project are shown in Table 1.

SF Health Facilities are point features with the location and information for the health facilities in San Francisco County, with a field “type” to distinguish those aiming for senior health.

The spatial boundaries used in this project are the SF Census Blocks dataset from DataSF. This dataset was used not only for map production but also as the join layer for other datasets. It also contains population data with age, for us to use a field calculator to get the senior population(age 65+).

The Economy data include food stamps, population percentage with an income lower than the poverty level, population percentage that has at least one kind of health insurance, and population percentage with education.

The Environmental Justice Index from CDC is the dataset containing the health vulnerability indicators for the senior population in San Francisco County, such as the high estimated prevalence of cancer, high blood pressure, and diabetes. The choice of the three indicators was because we think these diseases are more prevalent among the senior population.

Datasets	**Source**	**Description**
SF Health Facilities [1]	DataSF	Point feature of health facilities in SF(with type senior health or others)
SF Census Blocks [2]	DataSF	Boundary and senior population
SF Economy Data	Esri	Food stamps, Poverty, Health Insurance, and Education to enrich the census blocks data
Environmental Justice Index(EJI)[3]	CDC	Health Vulnerability Indicators: High estimated prevalence of cancer, high blood pressure, and diabetes

Table.1 Dataset Table

Our study area of this project is San Francisco County as shown in Fig.1, the most densely populated county in California, the western part of the United States. San Francisco County holds a population of 83,965 in 2020, with about 15.9% of the population aged 65 years or older. The datasets used in the project also applied to the Fig.1 map, including the health facility points and the census blocks with a senior population as the symbology color bar.

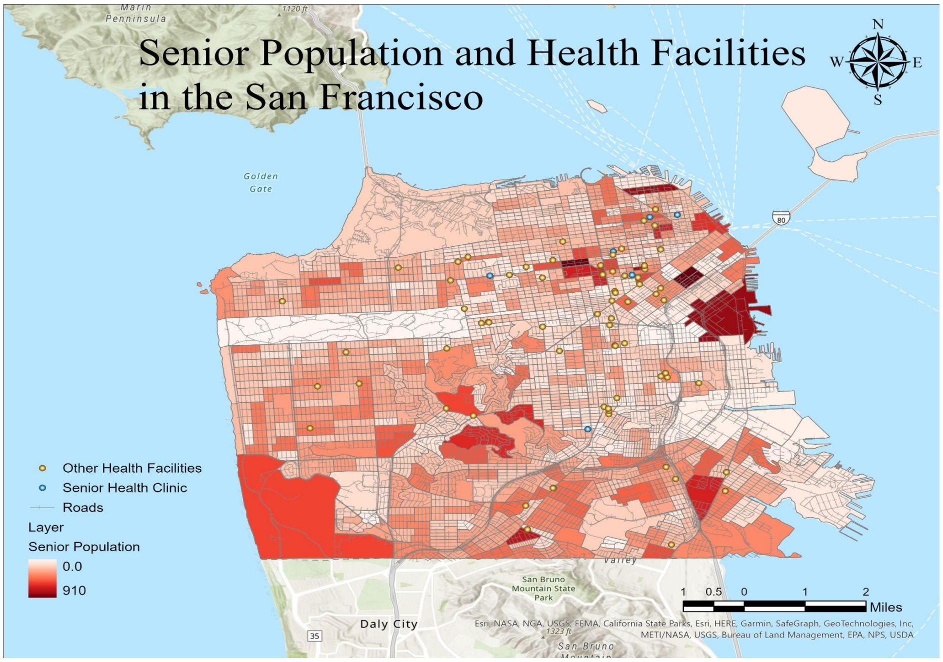

Fig.1 Study Area and spatial data

3 Methods

In this project, we modified and developed the Food Desert Project[4] to show accessibility to healthcare facilities for each census tract. The process is demonstrated below (Fig. 2).

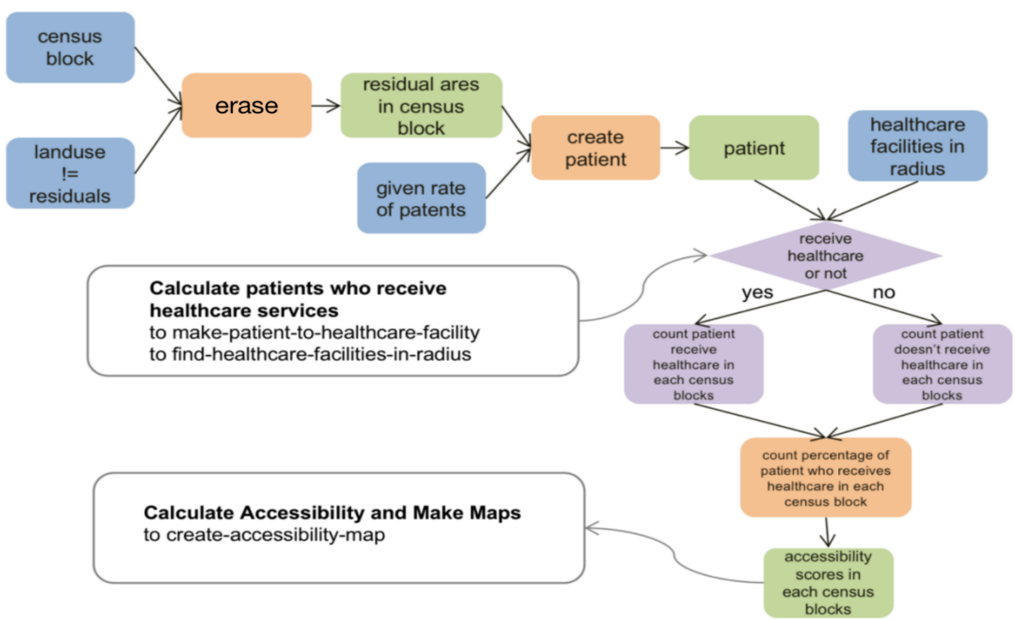

Fig.2 Project Workflow

3.1 Data Preparation

This project uses NetLogo 6.3.0, where the healthcare facility model will be built. According to the NetLogo GIS Extension[5], NetLogo only supports limited specific kinds of coordinate systems and projections. To fit the coordinate system to NetLogo,all the datasets are projected into NAD83.

With the help of the Join and Enrich tool in ArcGIS Pro, all the data has been merged into one layer - the Census Blocks Group layer. Health indicators from the EJI were joined to the Census Blocks data on the GEO_ID field. The Enrich tool is used to join the economy data found in Esri's data portal to the census blocks as Fig.3 shows.

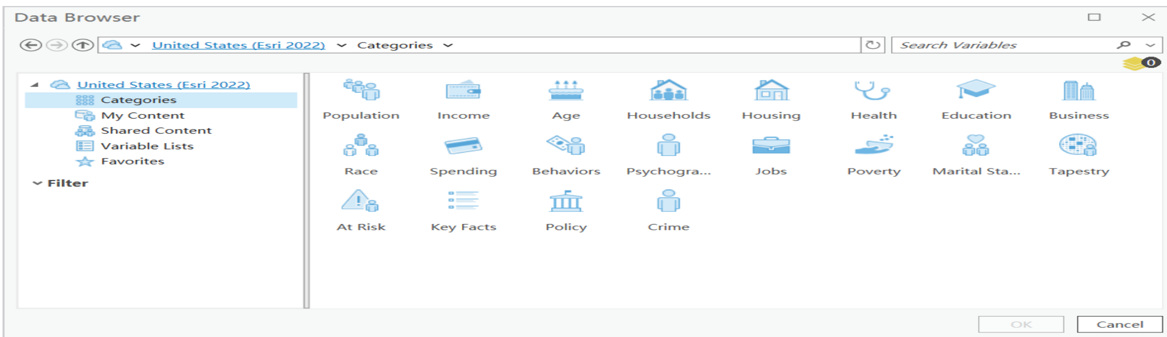

Fig. 3 Data enrich

3.2 Code Editing

The codes take the Food Desert project (Fig. 4) as a reference, which uses a spatially explicit agent based model to model the population of Washington DC, their accessibility to food, and their health status.

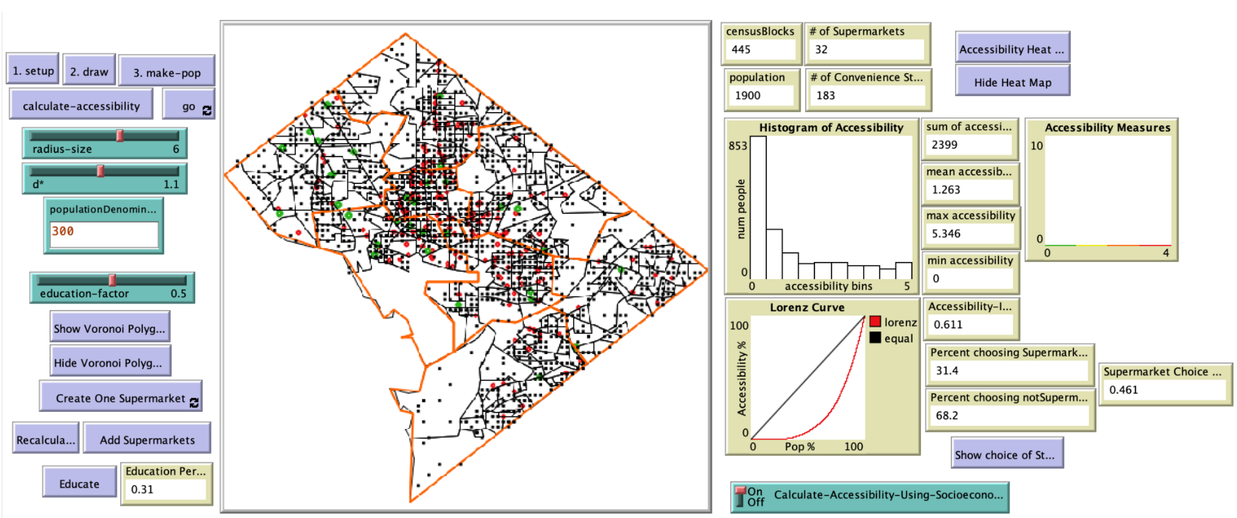

Fig. 4 Food Desert Project

In the Food Desert project, the author created global variables used for all functions, and patches attributes to store indicators at the census tract level, such as obesity, heart disease, and overall health score. Since the agents in that project are people who live in Washington DC, they breed people to customize their own attributes. The codes are shown below (Fig. 5):

```
extensions [ gis csv ]
globals [
  supermarkets ;a vector dataset of points for supermarket locations
  notSupermarkets ;a vector dataset points for locations that are in the supermarket data but are marked "F" fo
  censusBlocks ; a vector dataset of polygons for the outline of census blocks
  wards
  Sj ;a variable from Guy's (1983) gaussian measure for food accessibility
  available-colors ; used in the creation of the voronoi polygons
  accessibility-index-reserve ;used in the creation of the accessibility index
  lorenz-points ;used in the creation of the lorenz curve graph
  temp-mean ; used to make the heat map of accessibility
  people-with-store
]

patches-own [
  GEOID ;the unique ID associated with each census block
  education ;the education value from the census dataset
  population ;the population value from the census dataset
  foodstamps ;the foodstamps value from the census dataset
  poverty ;the poverty value from the census dataset
  centroid? ;is TRUE is the patch is the center of the polygon (i.e. the center of the census block)
  person-here? ;is TRUE is there is a person on the patch...used in the creation of the population of people
  store-score ;the accessibility score for each store for a unique person...one store can have different store-
  supermarket-here? ;marked TRUE is there is a supermarket on the patch
  notSupermarket-here? ;marked TRUE is there is a store that is not a supermarket on the patch
  obesity
  heartDisease
  overallHealth
  wardName
]

breed [people person]
people-own [
  edu ; [education] of patch-here) / ([population] of patch-here
  fs ; [foodstamps] of patch-here) / ([population] of patch-here
  pov ; [poverty] of patch-here) / ([population] of patch-here
  stores-in-radius ; patch set of patches with supermarket-here? = TRUE or notSupermarket-here? = TRUE
  accessibility ;a persons accessibility score
  countdown ; the number of days before a person "goes to the store"
  my-GEOID
  my-ward
  health
  heart
  overweight
  store-choice
]
```

Fig. 5 Definition Codes of Food Desert Project

This project does the same step but with the goal for healthcare accessibility. Global variables store variables for calculating accessibility scores. Patches attributes include boolean variables to store the population and healthcare facilities information. And a patient's agentset is created to represent each patient and their individual attributes. The codes are shown below(Fig. 6):

```
extensions [ gis Csv palette]

globals [
  accessibility-index-reserve ; used in the creation of the accessibility index
  senior-clinics-dataset
  non-senior-clinics-dataset
  censusBlocks-dataset
  boundary
  GEOID-list
  ct-patient-num-list
  ct-patient-A-num-list
  ct-A-list
  senior-pops
  num-patients
  num-patients-today
  temp-ct-num-patients
  res
]

patches-own [
  tract-id ; the unique ID associated with each census block
  education ; the education percentage from the census dataset
  senior-in-ct ; the senior population from the census dataset
  OBJECTID
  poverty ; the poverty percentage from the census dataset
  disability ; the 1+ persons with disability percentage of household from the census dataset
  healthInsurance ; the percentage of senior people with 1 type of health insurance
  patient-here? ; is TRUE if there is a person on the patch...used in the creation of the population of people
  Clinic-here?
  seniorClinic-here? ; marked TRUE if there is a senior clinic on the patch
  clinic-name
  preference
  cancerValue
  highBloodPressure
  diabetesValue
  h-num-physicians
  h-positions ; how many position rn
  patient-A-num
  num-patients-in-patch
]

breed [patients patient ]
patients-own [
  p-edu ;
  fs ;
  p-pov ;
  p-disability
  p-health_ins
  healthcare-facilities-in-radius
;  patient-A? ; a person whether receive healthcare services or not
  my-GEOID
  p-cancer
  p-bpHigh
  p-diabetes
  patient-healthcare-facility
  patient-arrive-time
  patient-duration
  move?
]
```

Fig. 6 Definition Codes for Healthcare Accessibility Project

The second step is to set up geographic files and draw them in the NetLogo window. The Food Desert Project uses codes as Fig.7, and this project set up and drew maps by codes in Fig.8. It is notable that the healthcare facilities are divided into specific for seniors and not, which are colored as green and red circles respectively.

```
to setup ;load the gis data
  clear-all
  reset-ticks
  gis:load-coordinate-system (word "Data/Shaped DC CensusBlock Data.prj")
  set supermarkets gis:load-dataset "Data/DCSupermarkets.shp" ;;;this is the store location data
  set censusBlocks gis:load-dataset "Data/Shaped DC CensusBlock Data.shp"
  set notSupermarkets gis:load-dataset "Data/DCNOTSupermarkets.shp"
  set wards gis:load-dataset "Data/Shaped Ward and Health Data.shp"
end


to draw ; draw the map and apply the vector data to the rastor in netlogo for the socioeconomic data
  clear-drawing
  reset-ticks
  ; gis:set-world-envelope gis:envelope-of censusBlocks
  gis:set-world-envelope (gis:envelope-union-of ;(gis:envelope-of sites)
    (gis:envelope-of notSupermarkets)
    (gis:envelope-of supermarkets)
    (gis:envelope-of censusBlocks)
    (gis:envelope-of wards)
    )

  ask patches [set pcolor white]

  gis:apply-coverage censusBlocks "GEOIDABM" GEOID
  gis:apply-coverage censusBlocks "POP" population
  gis:apply-coverage censusBlocks "EDU" education
  gis:apply-coverage censusBlocks "POV" foodstamps
  gis:apply-coverage censusBlocks "FOODSTAMPS" poverty

  gis:apply-coverage wards "NAME" wardName
  gis:apply-coverage wards "HEALTHPER" overallHealth
  gis:apply-coverage wards "OBESITYRA" obesity
  gis:apply-coverage wards "HEARTDISE" heartDisease



  ;I would like to make sales volume the value used for the "Sj" variable in the accessibility calculation
  ;unfortunately the VectorDataset must be a polygon dataset; points and lines are not supported...so I'll save this code for later
  ;gis:apply-coverage supermarkets "SALESVOL" sales
  ;gis:apply-coverage notSupermarkets "SALESVOL" sales

  gis:set-drawing-color red
  gis:draw notSupermarkets 2
  mark-notSupermarkets
  gis:set-drawing-color green
  gis:draw supermarkets 3
  mark-supermarkets

  gis:set-drawing-color black
  gis:draw censusBlocks   1

  gis:set-drawing-color orange
  gis:draw wards 2

end
```

Fig. 7 Set Up Codes of Food Desert Project

```
to setup ; load the gis data
  clear-all
  reset-ticks
  set GEOID-list []
  set ct-patient-num-list []
  set ct-patient-A-num-list []
  set ct-A-list []
  set senior-clinics-dataset gis:load-dataset "Data/SFSeniorHealth_Project.shp"
  set non-senior-clinics-dataset gis:load-dataset "Data/SFNOTSeniorHealth_Project.shp"
  set censusBlocks-dataset gis:load-dataset "Data/SF_BlockGrps_Elder_A_Project/SF_BlockGrps_Elder_A_Project.shp"
  ask patches[
    set Clinic-here? False
    set seniorClinic-here? False
    set preference -1
    set patient-A-num 0
  ]
  load-patch-data
end

 to load-patch-data ; draw the map and apply the vector data to the raster in NetLogo for the socioeconomic data
   clear-drawing
   reset-ticks
   gis:set-world-envelope (gis:envelope-union-of;set the study area
     (gis:envelope-of senior-clinics-dataset)
     (gis:envelope-of non-senior-clinics-dataset)
     (gis:envelope-of censusBlocks-dataset)
   )

   foreach gis:feature-list-of censusBlocks-dataset[ ? ->
     ask patches gis:intersecting ? [
       set tract-id gis:property-value ? "GEOID"
     ]
   ]
   foreach gis:feature-list-of non-senior-clinics-dataset[ ? ->
     ask patches gis:intersecting ? [
       set Clinic-here? True
       set clinic-name gis:property-value ? "FACILITY_N"
       set preference 1
     ]
   ]
   foreach gis:feature-list-of senior-clinics-dataset[ ? ->
     ask patches gis:intersecting ? [
       set seniorClinic-here? True
       set Clinic-here? True
       set clinic-name gis:property-value ? "FACILITY_N"
       set preference 2
     ]
   ]
   ifelse file-exists? "./Data/SF_CensusBlock_ex/censusblocks_attributes.txt"
   [
     file-open "./Data/SF_CensusBlock_ex/censusblocks_attributes.csv"
     while [not file-at-end?]
     [
       let line csv:from-row file-read-line
       let GEOID item 1 line
       set GEOID-list lput GEOID GEOID-list
;       show GEOID
       let M_F_ELDER item 9 line
       let ct-pov item 13 line
       let ct-disability item 14 line
       let ct-health_ins item 15 line
       let ct-edu item 17 line
       let ct-cancer item 19 line
       let ct-bpHigh item 20 line
       let ct-diabetes item 21 line
       ask patches with [tract-id = GEOID][
;         set ct-here? True
         ;attributes for agents
         set education ct-edu
         set poverty ct-pov
         set cancerValue ct-cancer
         set highBloodPressure ct-bpHigh
         set diabetesValue ct-diabetes
       ]
     ]
     foreach GEOID-list [ x ->
       set ct-patient-num-list lput 0 ct-patient-num-list
       set ct-patient-A-num-list lput 0 ct-patient-A-num-list
       set ct-A-list lput 0 ct-A-list
     ]
     print "set up patches with attributes completed!"
     file-close
   ]
   [user-message "There is no txt file for census blocks"]
   draw
 end

 to draw

   ask patches [set pcolor white]
   ;  mark Senior Clinics
   gis:set-drawing-color gray
   gis:draw censusBlocks-dataset  0.5

   gis:set-drawing-color green
   gis:draw senior-clinics-dataset 3
   gis:set-drawing-color red
   gis:draw non-senior-clinics-dataset 3

 end
```

Fig. 8 Set Up Codes of Healthcare Accessibility Project

After setting up all the data sources, patients and healthcare facilities are set in Fig.9.

In this process, the senior population is set as senior-pops with 134981, given in the SF Census Blocks dataset. Since there is no dataset to show the number of senior patients who will go to healthcare facilities, the num-patients is created to store the total senior patients number, presumed based on the input variables called patient-ratio, which will range from 0 to 60 percent. To simulate patients getting healthcare services, num-patients-today is created to represent the number of patients who will go to the healthcare facilities on the same day. From the research: Health Status and Health Care Service Utilization[6] mentioned that “on average, older adults visit physicians’ offices twice as often as do people under 65, averaging 7 office visits each year and totaling approximately 248 million visits in 2005 (NCHS, 2007).” Therefore, num-patients-today is calculated by multiplying the num-patients-today with the probability that the patient will go to the hospital on a given day, say 0.019.

Then, all the patients are created on the patches with census tract ID. And all healthcare facilities are set h-positions with capacity of around 8, which means they will serve at most h-positions of senior patients. This means that not all patients who live in the given distance areas will get healthcare services, their appointment time and duration matter as well.

```
to make-patients
  set senior-pops 134981
  set num-patients round(senior-pops * patient-ratio / 100); 80989
;  let num-patients-variation (random-float 0.01 - 0.02)
  set num-patients-today round(num-patients * 0.019);https://www.ncbi.nlm.nih.gov/books/NBK215400/ => Mean number of senior patient
  print num-patients-today
  repeat num-patients-today
  [
    ask one-of patches with [ tract-id > 0] [  sprout-patients 1  ]
  ]
  ; calculate how many patient in one census tract?
  ask patients [
    set shape "person"
    set size 2
    set move? False
    let patch-where-patient-born patch-here
    ask patch-where-patient-born[
      set num-patients-in-patch (num-patients-in-patch + 1)
    ]
  ]
  ask patients [
    set patient-arrive-time ((random 35) + 1 );patients arrive time between 8am - 5pm, 1 tick = 15min, 8am = tick 0, 5pm = tick 36
    set patient-duration round(((random 4) + 1) * (duration + 1)) ; duration between 15min - 2h
    set p-edu [education] of patch-here
    set p-pov [poverty] of patch-here
    set p-cancer [cancerValue] of patch-here
    set p-bpHigh [highBloodPressure] of patch-here
    set p-diabetes [diabetesValue] of patch-here
  ]
;  ask patients[
;    set patient-A? False
;  ]
  print "set up patients completed!"
end

to make-healthcare-facilities
  ask patches with [Clinic-here? = True] [
    set h-num-physicians (8 + (random 8 - 4))
    set h-positions h-num-physicians

  ]
  print "set up healthcare facilities completed!"
end
```

Fig. 9 Creating Agentsets Codes

This project modified its own functions for patients to interact with other patients and their environment. The codes are shown in Fig.10. There are 3 functions, which are patients-move, calculate-accessibility, and go.

In patients-move, patient-arrive-time will determine when this patient will arrive at one healthcare facility, only when the time is up, the patients will depart from their homes. During this process, they will firstly know if there is a healthcare facility in their areas, which is calculated by the input of distance-tolerance. If there are no healthcare facilities, this patient will be considered as a person without accessibility. If there are senior and non-senior healthcare facilities, the patient will prefer to go to the senior healthcare facilities based on the healthcare facility attribute: preference. They also need to check if the selected healthcare facility has positions. If there are, they will move to that patch where the healthcare facility is located. Otherwise, they will be considered as not receiving healthcare services.

In the go function, one tick will be considered as 15 minutes. Each day will start from tick 0 to tick 36, which is 8 a.m. to 5 p.m., and reset all agentset and run make-patients and make-healthcare-facilities again.

While the model is running, the calculate-accessibility function makes it possible for users to see accessibility maps. Each census tract will have an accessibility score calculated by dividing the total number of patients who received healthcare services from the first day by the total number of patients who went to the healthcare facilities from the first day. The color scheme is "Divergent" "Spectral" 8, which will divide all census tracts into 8 classes with higher scores colored by red, and lower scores colored by blue.

```
to patients-move
  ask patients [
    if ticks = patient-arrive-time [
      let best-patch max-one-of patches in-radius distance-tolerance [preference]
;      print best-patch
      ifelse [preference] of best-patch = -1 [
        die
        print "no clinics"
      ][
        ifelse [h-positions] of patch-here < 0[
          die
        ][
          ifelse (36 - patient-arrive-time) < patient-duration [
            die
          ][
            ask patch-here[
              set patient-A-num patient-A-num + 1 ; if patient move, the original patch will add 1 to patient-A-num
            ]
;            pen-down
            set move? True
            move-to best-patch
            let clinic-patch patch-here
            ask clinic-patch [
              set h-positions (h-positions - 1)
            ]
          ]
        ]
      ]
    ]
  ]
end

to calculate-accessibility
;  foreach GEOID-list [ x ->
;    let ct-patches patches with [tract-id = x]
;    let ct-num-patients-A sum [patient-A-num] of ct-patches
;    set ct-patient-A-num-list lput ct-num-patients-A ct-patient-A-num-list
;  ]
  set ct-patient-A-num-list lput 0 ct-patient-A-num-list
  set ct-patient-num-list lput 0 ct-patient-num-list
  let len-GEOID length GEOID-list
  foreach range len-GEOID [i ->
    let temp-geoid (item i GEOID-list)
    let ct-patches patches with [tract-id = temp-geoid]
    let ct-num-patients-A sum [patient-A-num] of ct-patches
    ; sample (replace list): let updated-list replace-item 2 my-list (item 2 my-list + 1)
    set ct-patient-A-num-list replace-item i ct-patient-A-num-list ct-num-patients-A

    let ct-num-patients sum [num-patients-in-patch] of ct-patches
    set ct-patient-num-list replace-item i ct-patient-num-list ct-num-patients

    ifelse item i ct-patient-num-list = 0 [
      set res 0
    ][
      set res ((item i ct-patient-A-num-list) / (item i ct-patient-num-list))
    ]
    set ct-A-list replace-item i ct-A-list res
    ifelse color-map = true [ ;Switch button
      ask patients [
        set hidden? True
      ]
      ask ct-patches [
        set pcolor palette:scale-gradient palette:scheme-colors "Divergent" "Spectral" 8 (item i ct-A-list) (max ct-A-list) (min ct-A-list)
      ]
    ][
      ask patients [set hidden? False]
      clear-drawing
      draw
    ]
    set res 0
  ]
  print "accessiblility map is completed"

end
to go
  tick
  patients-move
  ask patients [
    if move? = True [
      set patient-duration (patient-duration - 1)
      if patient-duration < 0 [
        die
        let clinic-patch patch-here
        ask clinic-patch [
          set h-positions h-positions + 1
        ]
      ]
    ]
  ]
  if ticks = 36 [
    reset-ticks
    make-patients
    make-healthcare-facilities
  ]
end
```

Fig.10 Interaction Codes

Based on the codes, the window is designed and shown in Fig.11. To use this program, the process is to setup, set patient-ratio, make-patients, make-healthcare-facilities, set distance-tolerance, and go. The calculate-accessibility button will show the colored map and accessibility-distribution will show the accessibility scores distribution for census tracts. The additional duration button will change the duration time in healthcare facilities for all patients, which could be considered as a macro control.

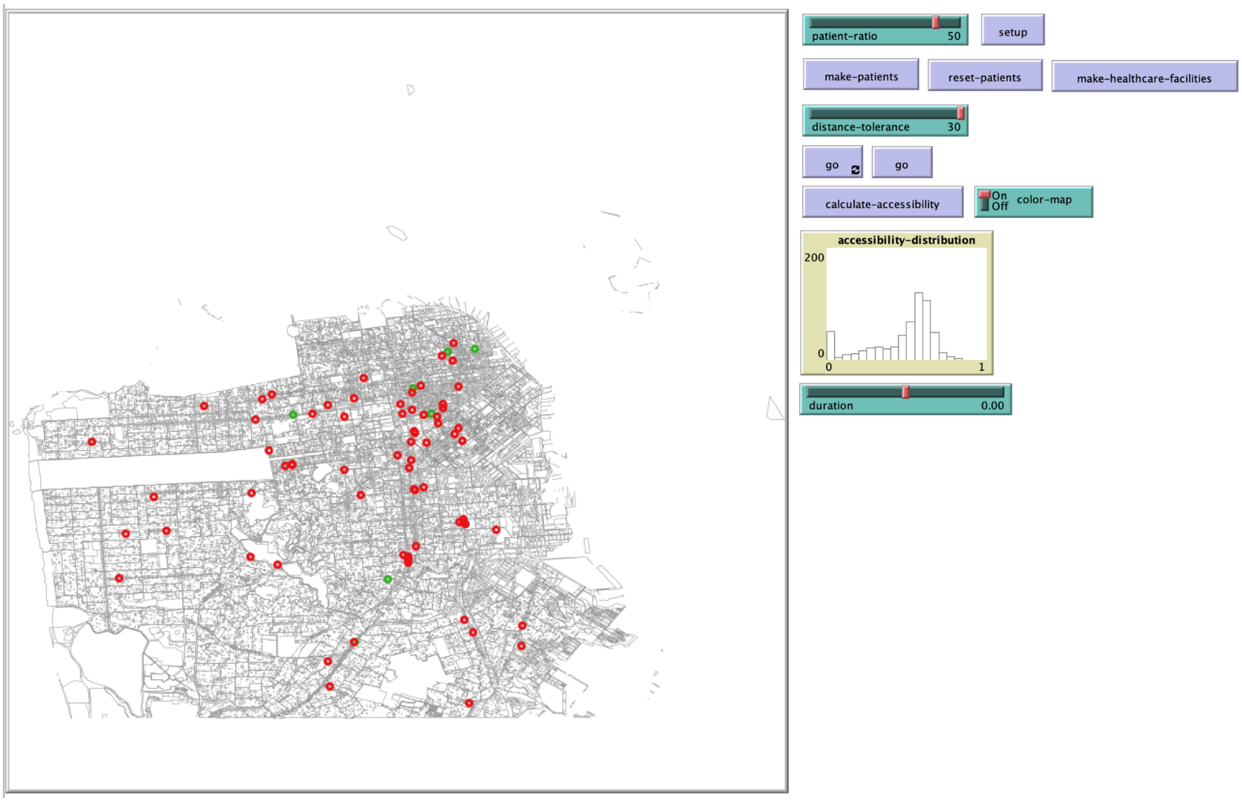

Fig. 11 Healthcare Accessibility Visual Interface

4 Results

4.1 Results Presentation

Fig.12(1) shows the 30-days accessibility map with patient-ratio is 60%, distance-tolerance is 20 patches. Fig.12(2) shows the next 30-days accessibility map after increasing patients' distance-tolerance to 30 patches. Fig.12(3)shows the next 30-days accessibility map after increasing 50% of duration time for all patients. Fig.12(4) shows the next 30-days accessibility map after decreasing 50% of duration time for all patients. Fig.12(5) shows the next 30-days accessibility map after decreasing distance-tolerance to 10 patches. Fig.12(6) shows all 5 situations' accessibility histograms.

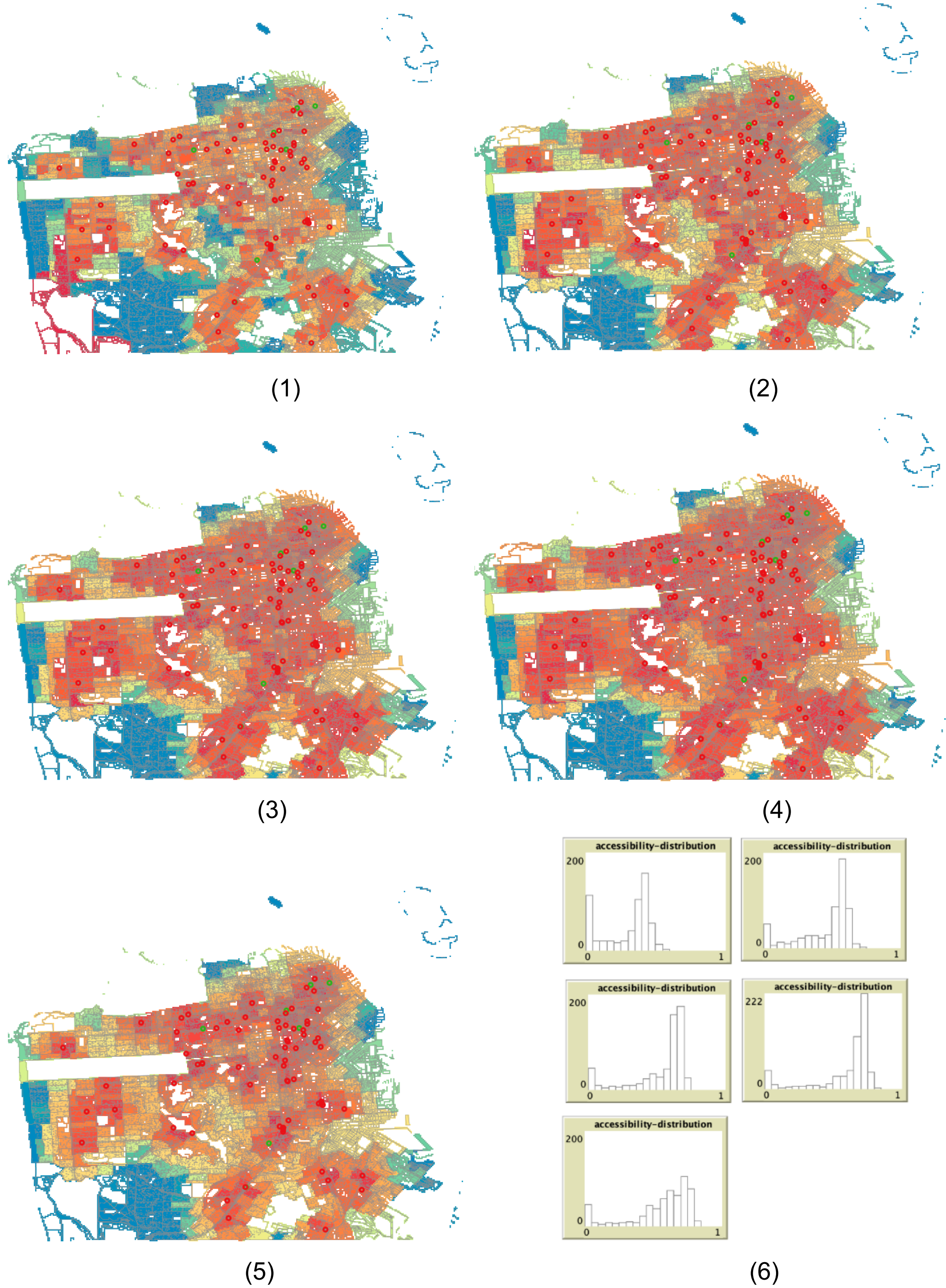

Fig. 12 Result Maps and Corresponding Accessibility Histograms

Firstly, based on the first 30-day simulation, the distribution of the accessibility heatmap for elderly healthcare services in San Francisco appears to be similar to the overall pattern observed in Project 3. The difference is that all healthcare facilities' capacity is set around 8, but a more detailed capacity dataset is applied in Project 3. From the result, the southwest region of San Francisco (south of Forest Hill) has generally lower accessibility, while the central region has higher accessibility, and there is a declining trend in accessibility along the coastal areas. After the distance-tolerance is increased, accessibility distribution shows more tracts have higher accessibility scores. And the 0-score census tract number drops a lot, which is in line with the expectation. Changing the time-duration of patients in healthcare facilities doesn't make a huge difference on accessibility scores. Only a small change in accessibility scores occurs in high accessibility areas. However, it is notable that reducing distance-tolerance by about 67% will hugely change the accessibility distribution.

Here are some conclusions based on the result map:

- The central area of San Francisco, including neighborhoods like SoMa (South of Market), Financial District, and Tenderloin, has relatively high accessibility, as indicated by the warmer colors (yellow, orange, and red) on the map.
- In contrast, the southwestern region of San Francisco, such as the area south of Forest Hill, appears to have lower accessibility, as shown by the cooler colors (blue and green) on the heatmap. This suggests that elderly residents in these areas may have difficulty accessing healthcare services.
- The coastal areas, particularly the eastern coast, including Mission Bay and Hunters Point, also exhibit lower accessibility, as indicated by the cooler colors (blue and purple). This may be due to factors such as limited healthcare facilities, transportation barriers, or distance from residential areas.
- The northern part of San Francisco, including neighborhoods like the Marina District and Sea Cliff, has pockets of low accessibility, as suggested by the presence of cooler colors (blue and purple) on the map. This indicates that certain areas within these neighborhoods may have limited access to healthcare services for the elderly population.

In summary, heatmap reveals that the accessibility of elderly healthcare services in San Francisco varies significantly across different regions. The central areas generally have higher accessibility, while the southwestern and coastal regions have lower accessibility. Moreover, there are pockets of low accessibility in the northern part of the city. Further analysis of these findings may help identify potential solutions to improve healthcare access for the elderly population in San Francisco.

4.2 Result Analysis

Our Netlogo program successfully simulated the healthcare accessibility scene to some extent. Upon analyzing the heatmap of elderly healthcare service accessibility in San Francisco, we can identify several factors that might influence the observed patterns. These factors include the city's topography, transportation infrastructure, and the distribution of healthcare facilities.

1. Transportation infrastructure: Public transportation and road networks are crucial in ensuring accessibility to healthcare services. Central areas of San Francisco, which display higher accessibility in the heatmap, are generally well-served by public transportation options like buses and light rail systems. This makes it easier for the elderly population to reach healthcare facilities. However, transportation options may be less frequent or accessible in certain coastal regions, such as South of Market, Mission Bay, and Hunters Point, contributing to the lower accessibility observed in these areas.
2. Distribution of healthcare facilities: The accessibility of healthcare services is directly influenced by the availability and distribution of healthcare facilities, including hospitals, clinics, and specialized elder care centers. The central areas of San Francisco have a higher concentration of healthcare facilities, leading to the higher accessibility observed in those regions. In contrast, areas with fewer or more dispersed healthcare facilities, like the southwestern region and coastal areas, may experience lower accessibility.

In summary, the accessibility of elderly healthcare services in San Francisco, as observed in the provided heatmap, may be influenced by factors such as the city's transportation infrastructure, distribution of healthcare facilities. A combination of these factors may be responsible for the observed patterns in the heatmap, with higher accessibility in central areas and lower accessibility in the southwestern, coastal, and northern regions. Further investigation into these factors could help identify potential interventions to improve healthcare access for the elderly population in San Francisco.

5 Discussion

While our project successfully utilized Agent-Based Modeling (ABMs) through NetLogo to analyze the accessibility of healthcare facilities for the elderly population in San Francisco and the result is decent, there is room for improvement in how we defined and selected the agents' properties and attributes. While we provided some information on the data used to define the agents, we did not provide a detailed explanation of how we selected and defined their attributes, and how selected attributes can influence the accessibility for each tract.

Additionally, we only used the code from the Food Desert project as a reference for editing our code, which may have limited our ability to fully customize the model to fit our project's specific needs. Future projects could benefit from more detailed explanations of how agents' properties and attributes were selected and defined, as well as more comprehensive code customization.

Compared with the 2SFCA method used in Project 3, there is no doubt that the result this time is more accurate and realistic than the result of project3. ABMs allowed us to incorporate additional datasets to better capture the complex interactions between agents and their environment.

By defining the agents as elderly residents and healthcare facilities, we were able to model the dynamic movement and interaction of agents within their environment. But there are more factors we can take into account, such as transportation infrastructure, residential density, and socio-economic status.

Here are some factors and reasons:

- Topography: San Francisco is characterized by its hilly terrain, which can create physical barriers and impact accessibility, especially for elderly individuals who might have mobility challenges. The steep inclines and declines can make it difficult for seniors to travel to healthcare facilities. This could explain the lower accessibility observed in some areas, such as the southwestern region (south of Forest Hill) and coastal regions.
- Residential density: Residential density can impact the demand for healthcare services and the allocation of resources, such as healthcare facilities and transportation infrastructure. Central areas of San Francisco typically have higher residential density, which may lead to greater investment in healthcare facilities and transportation options, thus improving accessibility. In contrast, lower residential density in areas like the southwestern region and coastal areas may result in less investment in healthcare infrastructure and transportation, contributing to the lower accessibility observed.
- Social and environmental factors such as Environmental Justice Index (EJI) index: EJI dataset is able to evaluate the fairness and equity of healthcare accessibility across different census blocks in San Francisco.

Additionally, in this project, we only calculate catchment for patients by Euclidean distance. It might be better to simulate patients traveling by car.

However, our model allowed us to identify potential interventions, such as distance tolerance and patient duration, which are able to guide the government to improve transportation infrastructure and provide funding to shorten the duration for patients.

Overall, the use of ABMs allowed us to provide a more comprehensive and nuanced analysis of healthcare accessibility for the elderly population in San Francisco, highlighting the potential benefits of incorporating ABMs in urban planning and policy-making.

6 Reference

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7 Appendix

Name	Practice	Report
Junhong Duan	NetLogo Programming, Data Searching, Result Generation, Workflow Presentation	Programming and Result
Lingduo Luo	Data Preparation, Literature Review, Result Generation	Introduction and Result
Ruochen Liang	Data Searching, Literature Review	Data preprocessing and Programming
Shiqi Li	NetLogo Programming, Data Searching, Literature Review, Data Preparation	Data preprocessing and Programming
Yongchun Chen	Data Searching, Literature Review	Discussion

Table. 2 Individual Contribution