Healthcare Accessibility in Chicago Region

Yaxiong Shao

Department of Geographic and Atmospheric Sciences, College of Liberal Arts and Sciences, Northern Illinois University

Northern Illinois University

Introduction

Higher quality healthcare is associated with better health outcomes, better patient experiences, and lower health inequity, at lower costs. Access to healthcare is influenced by many factors, the supply of healthcare services, demand for healthcare, the population's health status, demographic characteristics, socioeconomic status, and geographical impedance between a population and healthcare services. Accurate modeling of the spatial accessibility of healthcare is critical to measuring and responding to doctor shortages. Two-Step Flow Catchment Area model takes both supply side and demand side into consideration, Rational Agent Access Model considers to minimize the combined accessibility and availability costs at the point of care. In this research, we will make a comparison between the Two-step Floating Catchment Area Model results and Rational Agent Access Model results.

Data

- Doctor data crawl from Sharecare.com
- Block level shapefile download from Census Bureau
- Tract level shapefile download from Census Bureau
- Block Level Population data download from Census Bureau
- OpenStreetMap Road Networks extract from Overpass API
- Road Networks speed limit data

Process Flow Chart

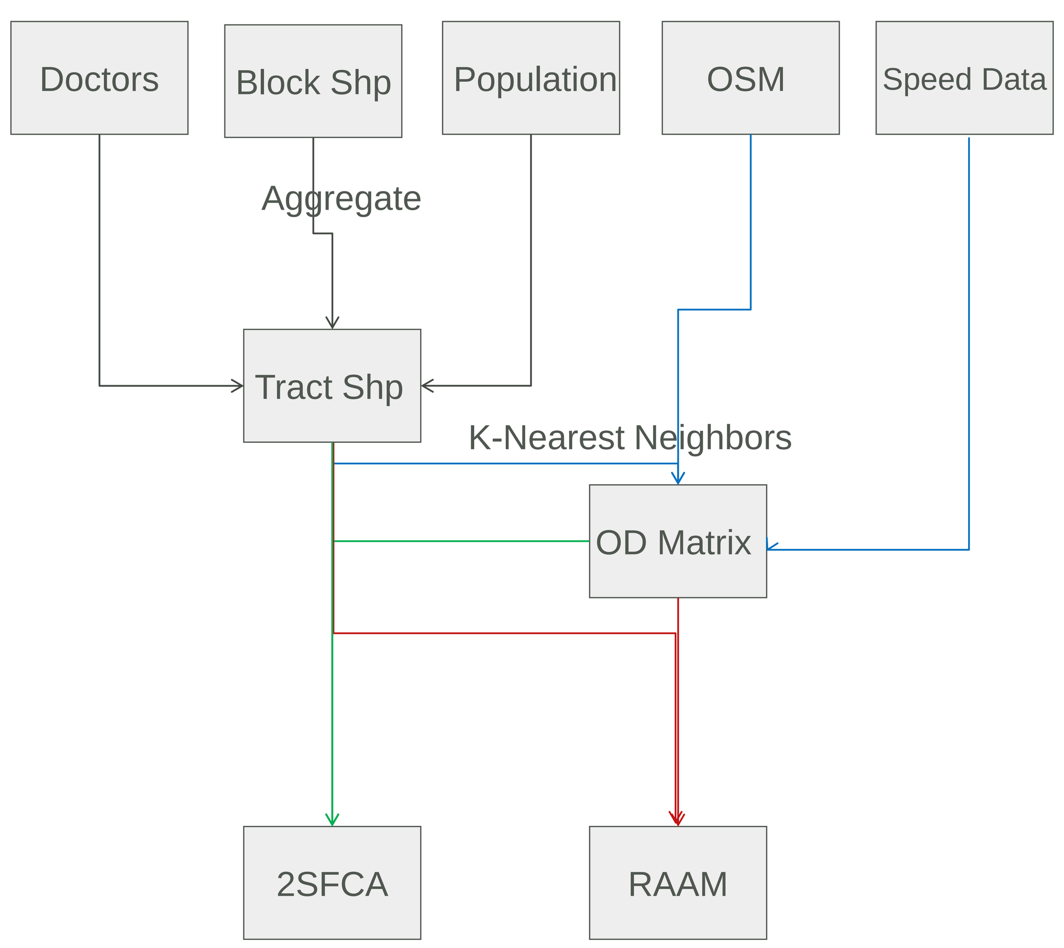

Figure 1. Data Process Flow Chart

Method

Origin-Destination Matrix (OD Matrix)

Origin-Destination (OD) matrix was calculated as follow:

1. Using spatial join tool to calculate the total doctors in each block
2. Using C# calculate weighted centroid from blocks level to tracts level
3. Using Overpass API to extract OpenStreetMap road networks
4. Import Doctor centroid and population centroid data to PostgreSQL
5. Using osm2pgrouting tool loading OSM road networks to PostgreSQL
6. Drop unconnected road networks
7. Using K-Nearest Neighbors to calculate nearest node in road networks for each weighted centroid
8. Import road speed limit data into PostgreSQL
9. Using PostGIS and PgRouting to calculate the Origin-Destination matrix.

Two-Step Flow Catchment Area (2SFCA)

1. For each supply location j, search all demand locations (k) that are within a threshold travel distance (d_0) from location j (i.e., catchment area j), and compute the supply-to-demand ratio R_j within the catchment area:

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \le d_0\}} D_k}$$

2. Next, for each demand location i, search all supply locations (j) that are within the threshold distance (d_0) from location i (i.e., catchment area i), and sum up the supply to demand ratios R_j at those locations to obtain the accessibility A_i^F at demand location i:

$$A_i^F = \sum_{j \in \{d_{ij} \le d_0\}} R_j = \sum_{j \in \{d_{ij} \le d_0\}} \left(\frac{S_j}{\sum_{k \in \{d_{kj} \le d_0\}} D_k} \right)$$

3. A larger value of A_i^F indicates a better accessibility at a location.

Rational Agent Access Model (RAAM)

1. The cost of care is defined as the sum of the congestion and travel costs. The "congestion cost" is the observed inverse PPR at (patients per provider), accounting for demand by residents from all residential locations, and normalized by a factor ρ: $\left(\sum_{r'} d_{r'\ell}/s_\ell\right)/\rho$. we denote the fixed supply of doctors at location ℓ by s_ℓ , and travel times by $t_{r\ell}$.

2. The travel cost is simply the time $t_{r\ell}$ from an agent's residence r to ℓ normalized by a parameter τ. This parameter sets the cost or disutility of travel relative to congestion. The total cost for a resident of r to receive care at is thus

$$\mathrm{RAAM}(r,\ell) \equiv \frac{\sum_{r'} d_{r'\ell}/s_\ell}{\rho} + \frac{t_{r\ell}}{\tau}.$$

3. Assuming that patients seek care at the cheapest location, thus, the choice of an agent at r can be expressed by the decision rule:

$$\underset{\ell}{\operatorname{argmin}} \left[\mathrm{RAAM}(r,\ell)\right].$$

Conclusions

This project has developed a faster method to calculate the OD Matrix. Then presented 2SFCA and RAAM models for calculating spatial accessibility of healthcare in Chicago region. 2SFCA accounts for both supply side and demand side. RAAM minimizes their combined access (travel time) and availability (doctor's office congestion) costs.

Results

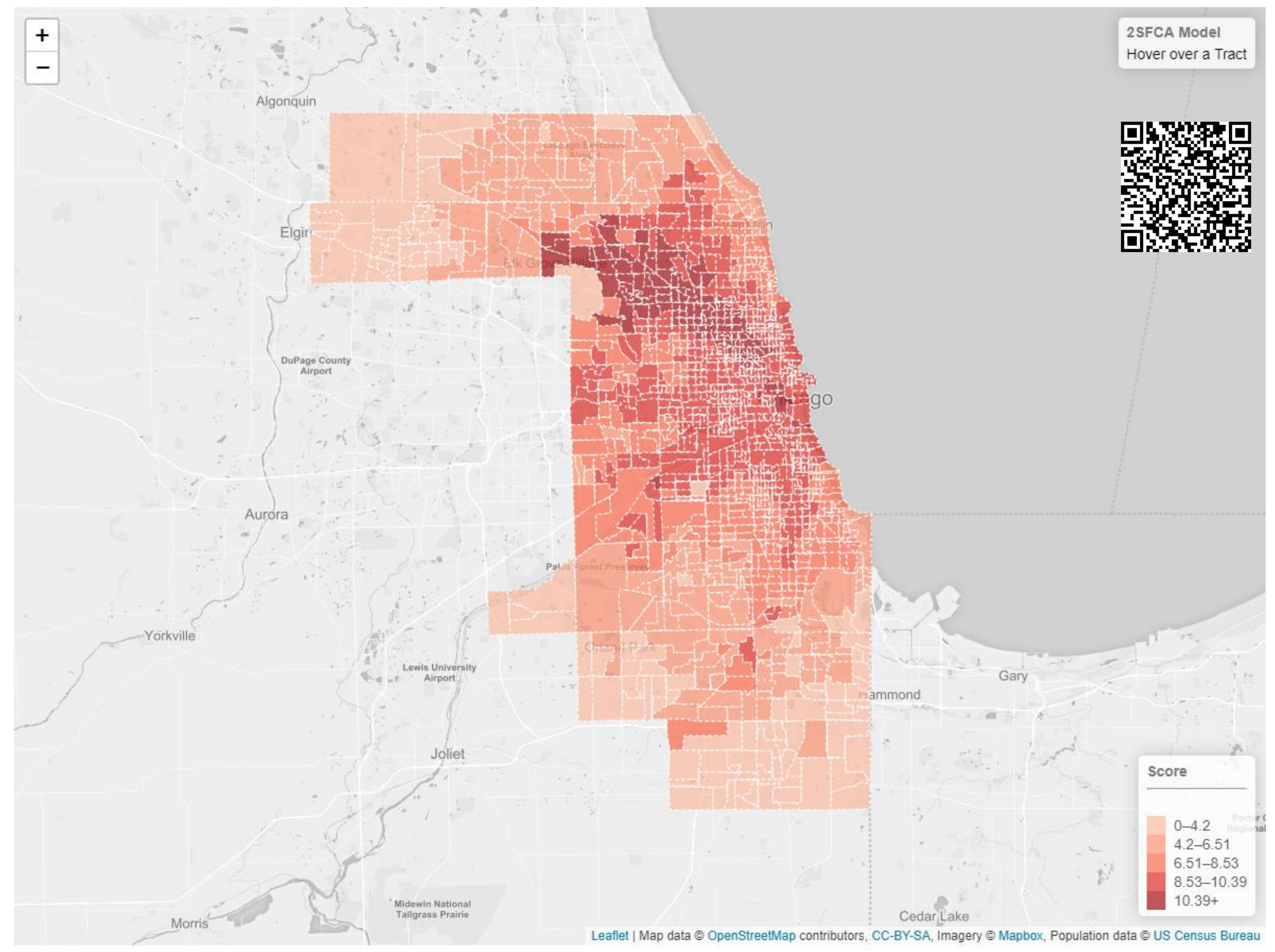

Figure 2. 2SFCA Accessibility Scores

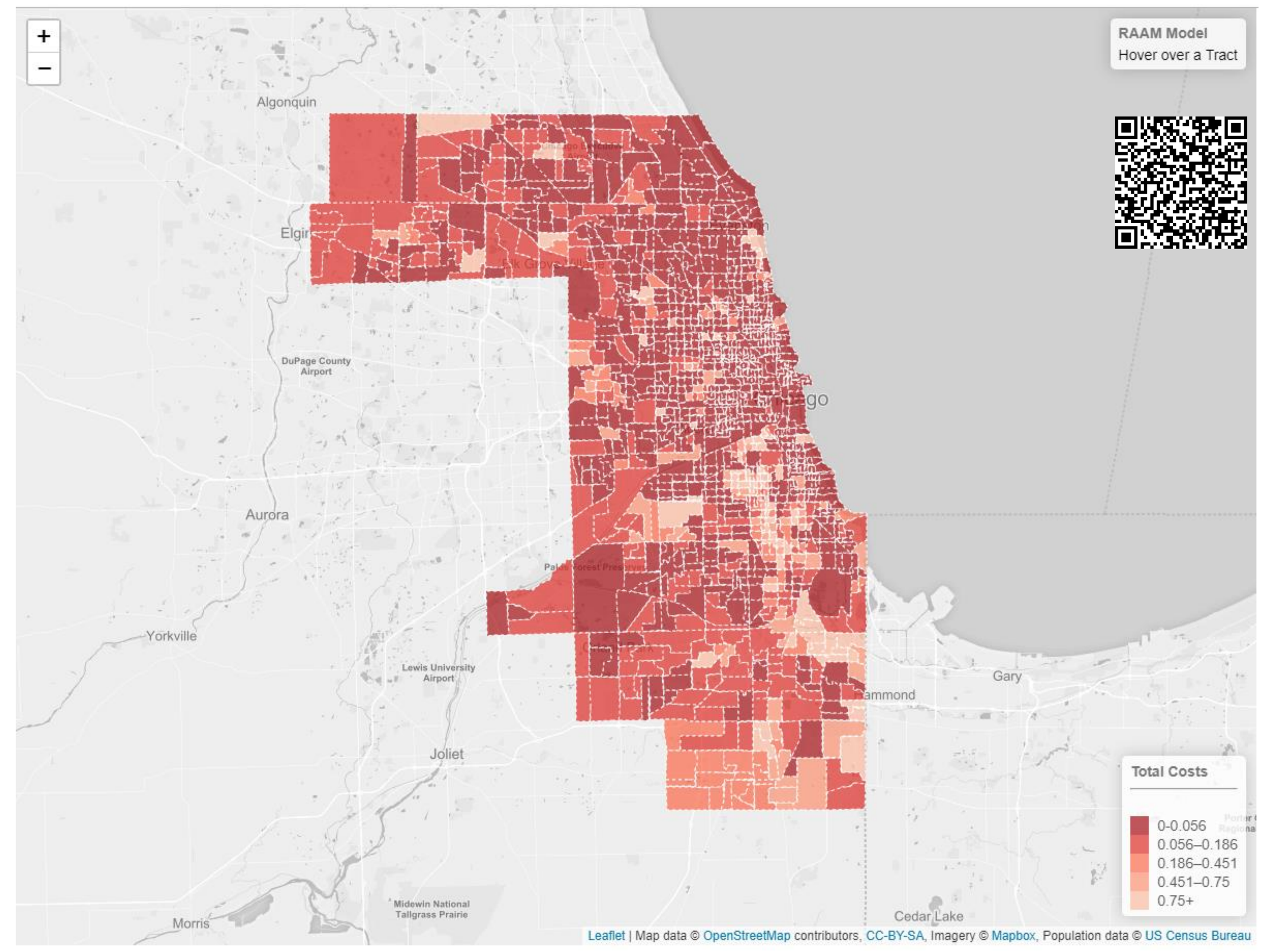

Figure 3. RAAM Accessibility Costs

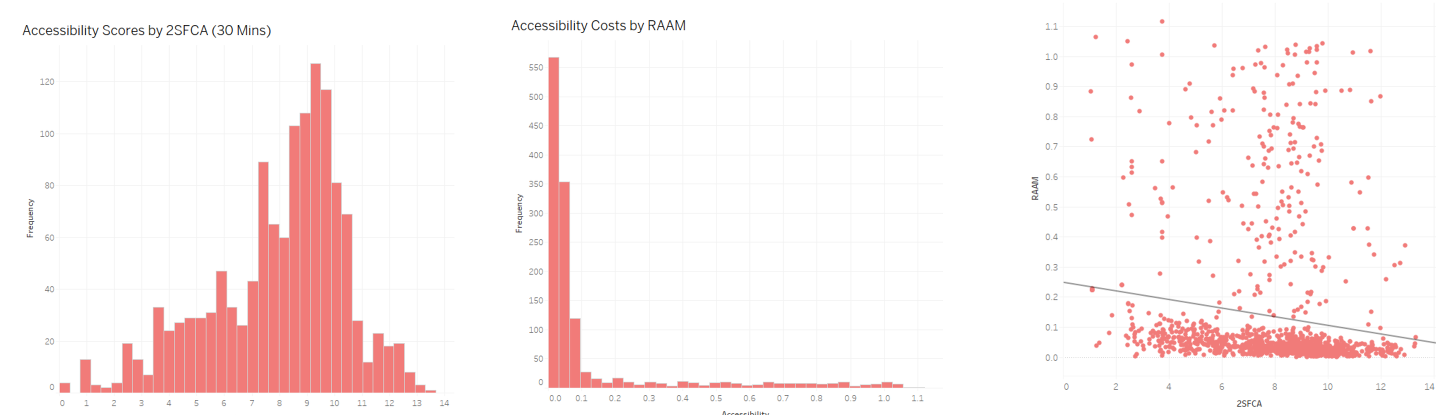

Figure 4. Comparison of accessibility scores by the 2SFCA and RAAM Models

Figure 4a shows the distribution by the 2SFCA method (skewed toward high scores). Figure 4b shows the distribution by the RAAM method (large amounts of tracts are located in low costs range). Figure 4c plots them in one graph, showing there is a negative correlations.