Spatial Neighbors and Neighborhoods

GEOG 215 - March 25, 2020

Today's Agenda

- Spatial Neighborhoods and Neighbors
  - What is a neighborhood
  - How is a neighborhood defined
    - Absolute Distance approach
    - Continuous Distance approach
    - Relative Distance approach
    - Neighborhood weights matrix
    - Thiessen Polygons
    - Connectivity

Polleverywhere

http://pollev.com/goelvarun553

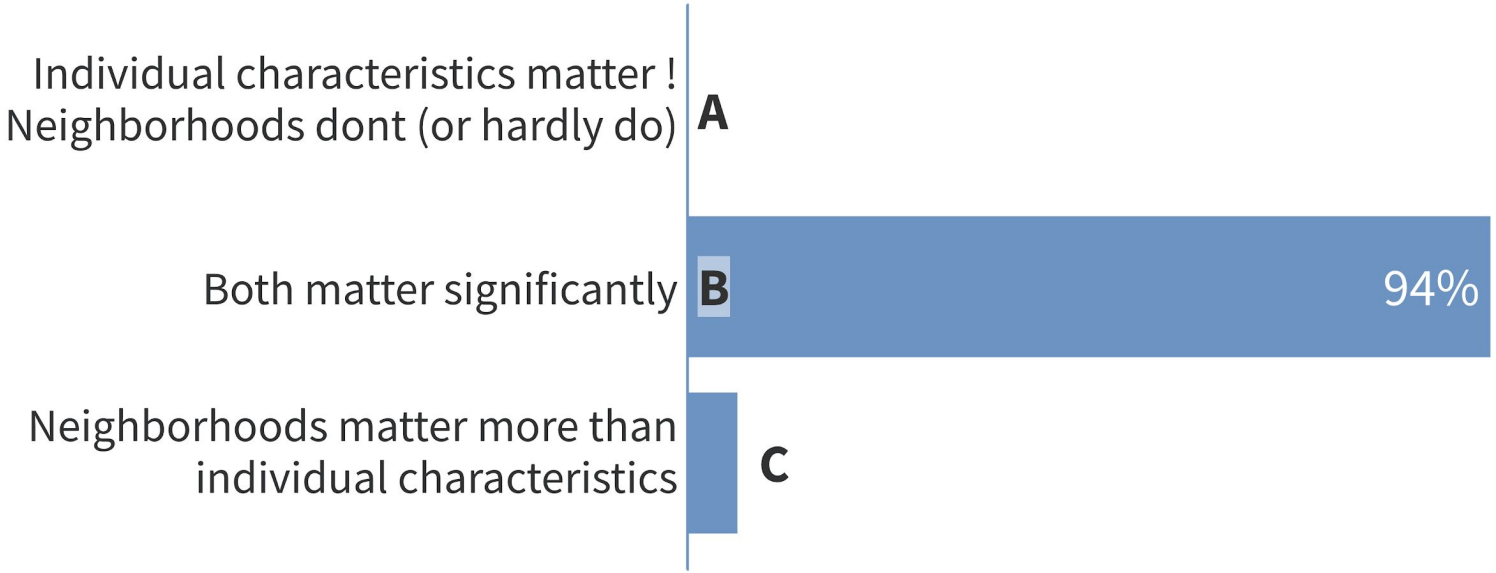
Choose 1 choice in survey 1:
Your neighborhood can be your family, your house neighbors, your friends, your school, etc

You individual outcomes can be anything - your grades, your earnings, your mental health state, your anxiety levels during an exam, your access to health food, etc

Survey 2
Word Survey - Think about constitutes your neighborhood/ neighbors, you can also write emotions - good/bad. Or any other characteristic

Results from Polleverywhere -1

According to you, how much do you think your individual outcomes are dependent on your own individual characteristics compared to your neighborhood characteristics ?



Results from Polleverywhere -2

What words come to your mind when you think about your `neighborhood` or `neighbors` ?

Neighborhoods matter

The Best and Worst Places to Grow Up: How Your Area Compares

MAY 4, 2015

Children who grow up in some places go on to earn much more than they would if they grew up elsewhere. RELATED ARTICLE

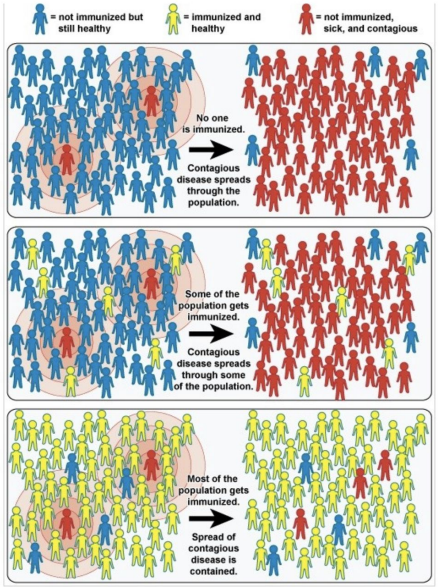
From health to happiness, how neighbors impact our lives

LIFE OR DEATH

Map: What story does your neighborhood's life expectancy tell?

Study Says Obesity Can Be Contagious

Zip code better predictor of he[illegible]h than genetic code



Credit: NIAID

Define your Neighborhood

Recall

- Tobler's first law of Geography
  - *Everything is related to everything else, but near things are more related than distant things*
    - Values at locations near each other tend to be similar, with similarity decreasing with distance
  - Implies that phenomena are not distributed randomly (throughout space)
    - Imagine how the world would appear if everything were randomly distributed

Neighborhood

- What is a neighborhood?
  - Neighborhood has many definitions
    - Zone of influence
    - Group/Region
    - Idea of nearness or connectedness
  - Things or objects that are near one another
  - Things or objects that affect one another
- Why important?
  - To identify neighbors, we first have to define what is a neighborhood

Neighbors

- Neighbors are features located within a neighborhood
  - To describe or characterize spatial relationships among objects requires us to define the neighbor relationships
    - Neighbors for each observation!
    - Your relationship to your neighbors can be defined in multiple ways
      - Some neighbors matter more than others

Neighbors

- Importance in spatial data science
  - Many (all?) tests that integrate “space” or “position” require some form of neighborhood definition or the identification of neighbors
- Quite literally, spatial analysis is built upon understanding relationships among neighboring features!
- Has huge implications for regular statistics too
  - Not accounting for neighborhood effects violates core assumptions of statistical models
    - Each observation is independent of each other ?
  - Not accounting for neighborhood effects does not give us full picture of factors impacting our individual outcomes or behaviors.

Neighbors

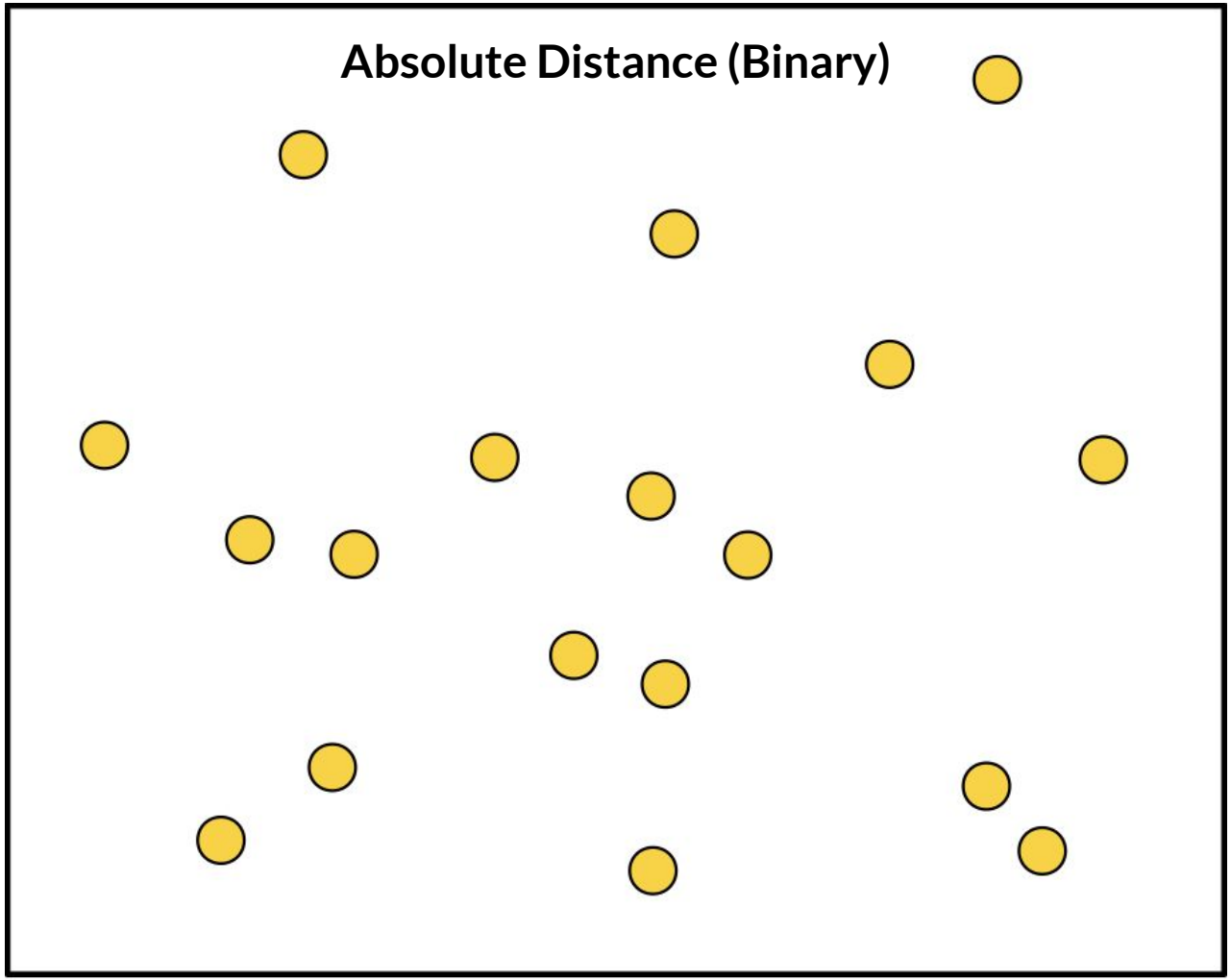
- Basic approaches to characterize neighbors
  - Binary (Y,N)
    - Either you are a neighbor, or not
  - Continuous
    - Amount of “neighborliness”
      - Generally, based on distance
      - On a conceptual level, some neighbors may be strong, while others are weaker

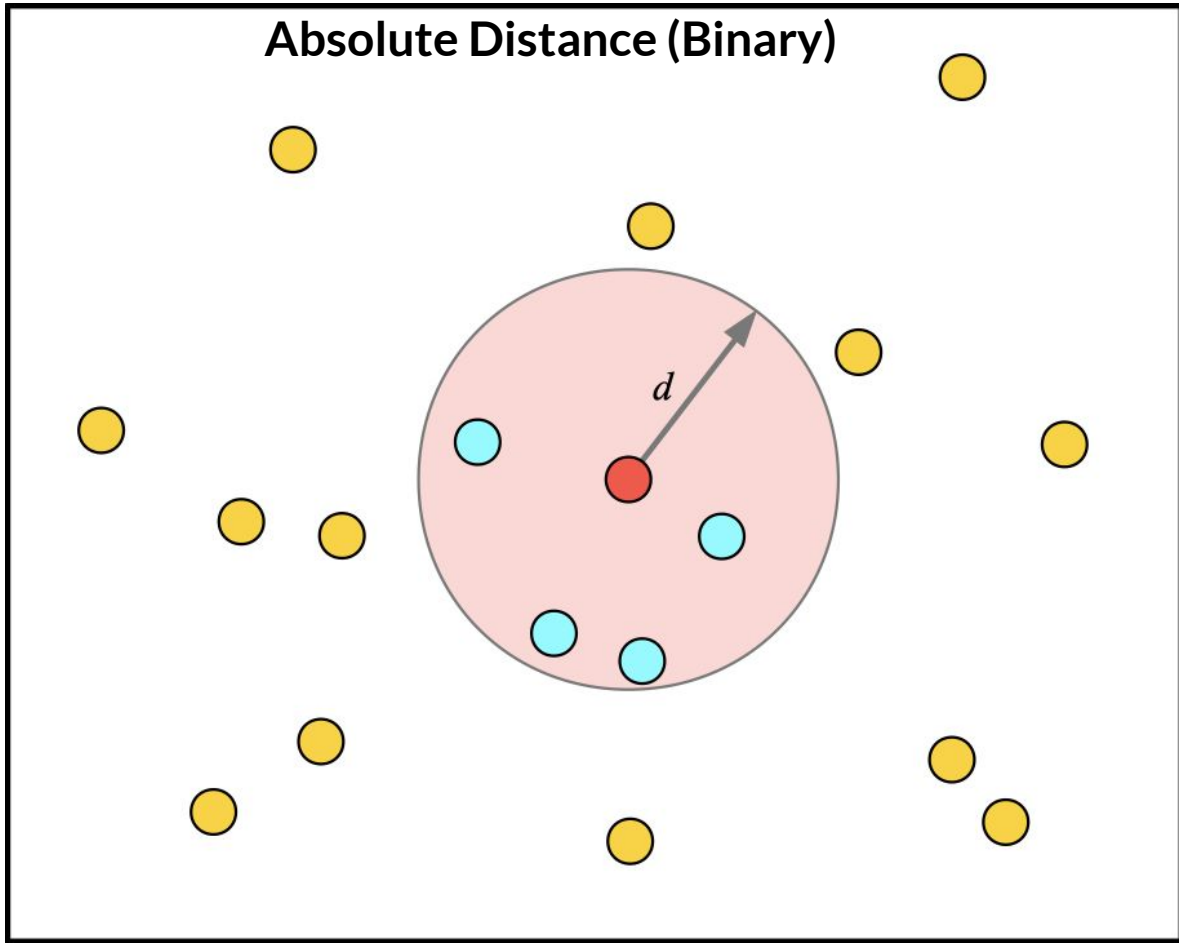
Neighbors

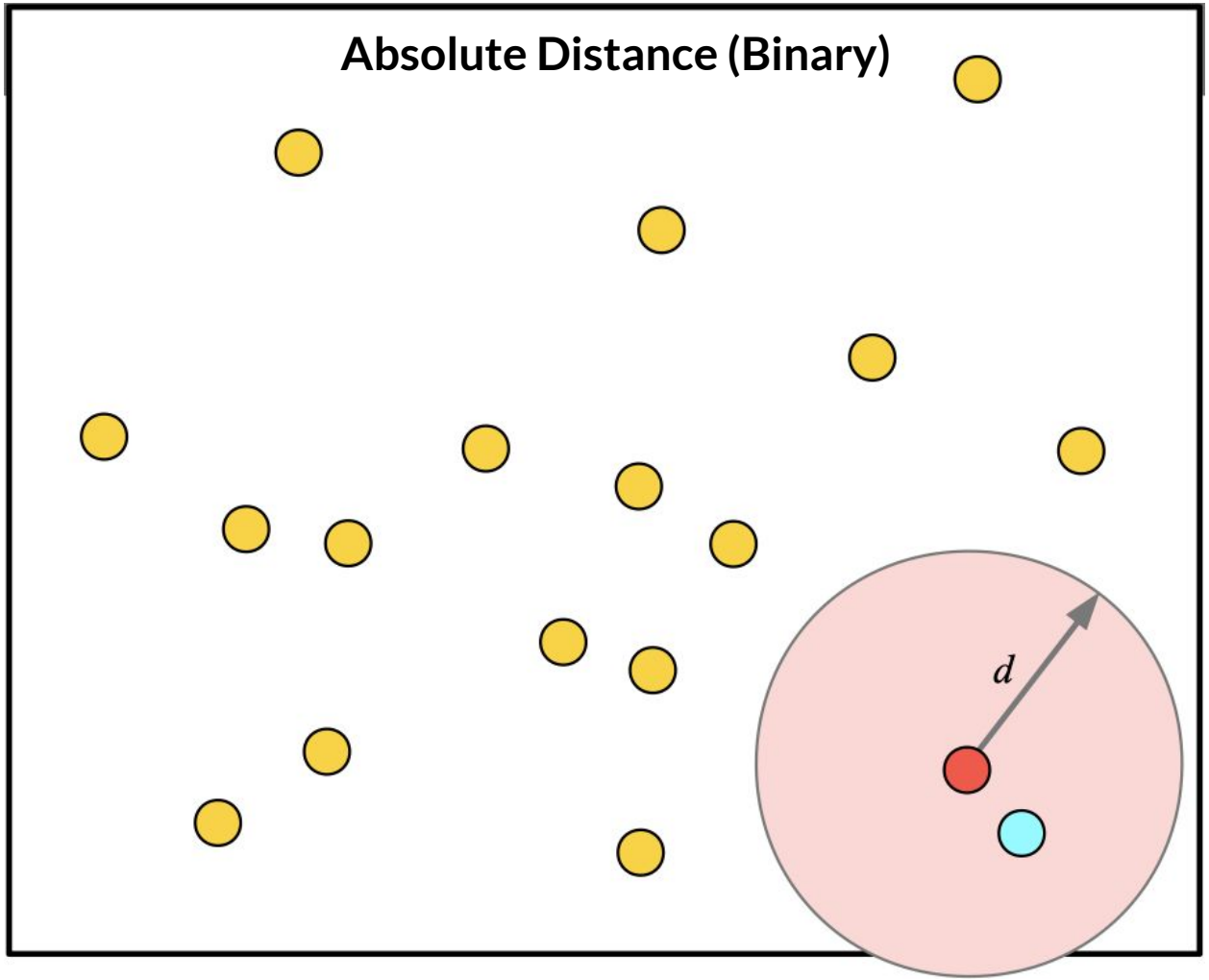
- Basic approaches to characterize neighbors
  - Absolute distance
    - Objects are considered neighbors based upon the actual distance separating them
  - Relative distance
    - Nearest feature
      - The nearest feature is considered a neighbor
      - Or, nearest *k* features
    - Topology-based
      - Connecting features are considered neighbors

Neighbors

- Absolute distance approach
  - Objects are considered neighbors based upon a pre - determined threshold distance
  - For points
    - Distance between points
  - For polygons
    - Distance between polygon centroids
  - Examples
    - People within 1 km of a polluting site
    - Children with 5 km of a school
    - All grocery stores within my walking distance
    - Others ?


Absolute Distance (Binary)


Absolute Distance (Binary)
d


Absolute Distance (Binary)
d

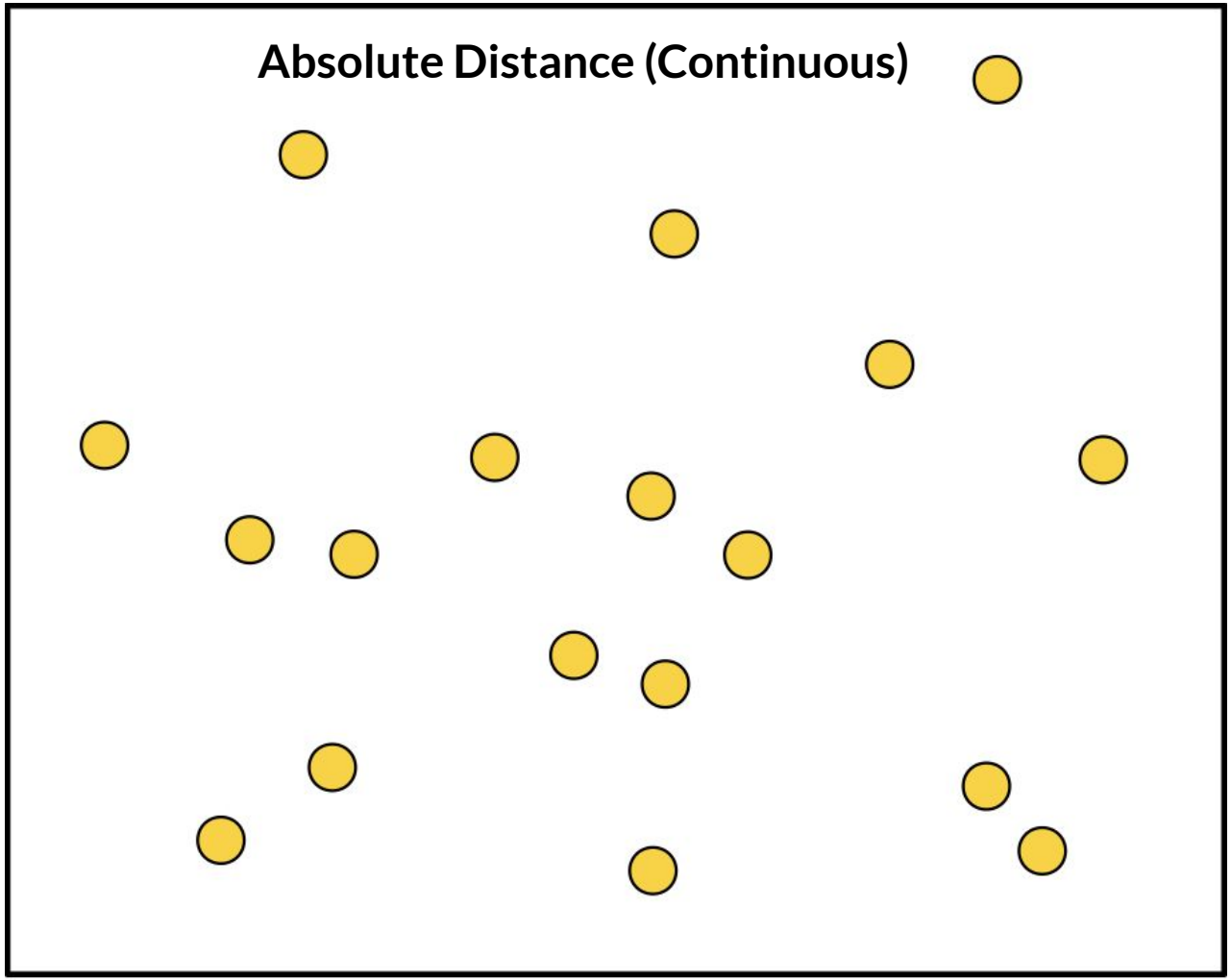
Continuous Distance Neighbors

- Strength or **weight** of neighbor relationship determined by using an “inverse” relationship with distance
  - Short distance = High weight
  - Long distance = Low weigh

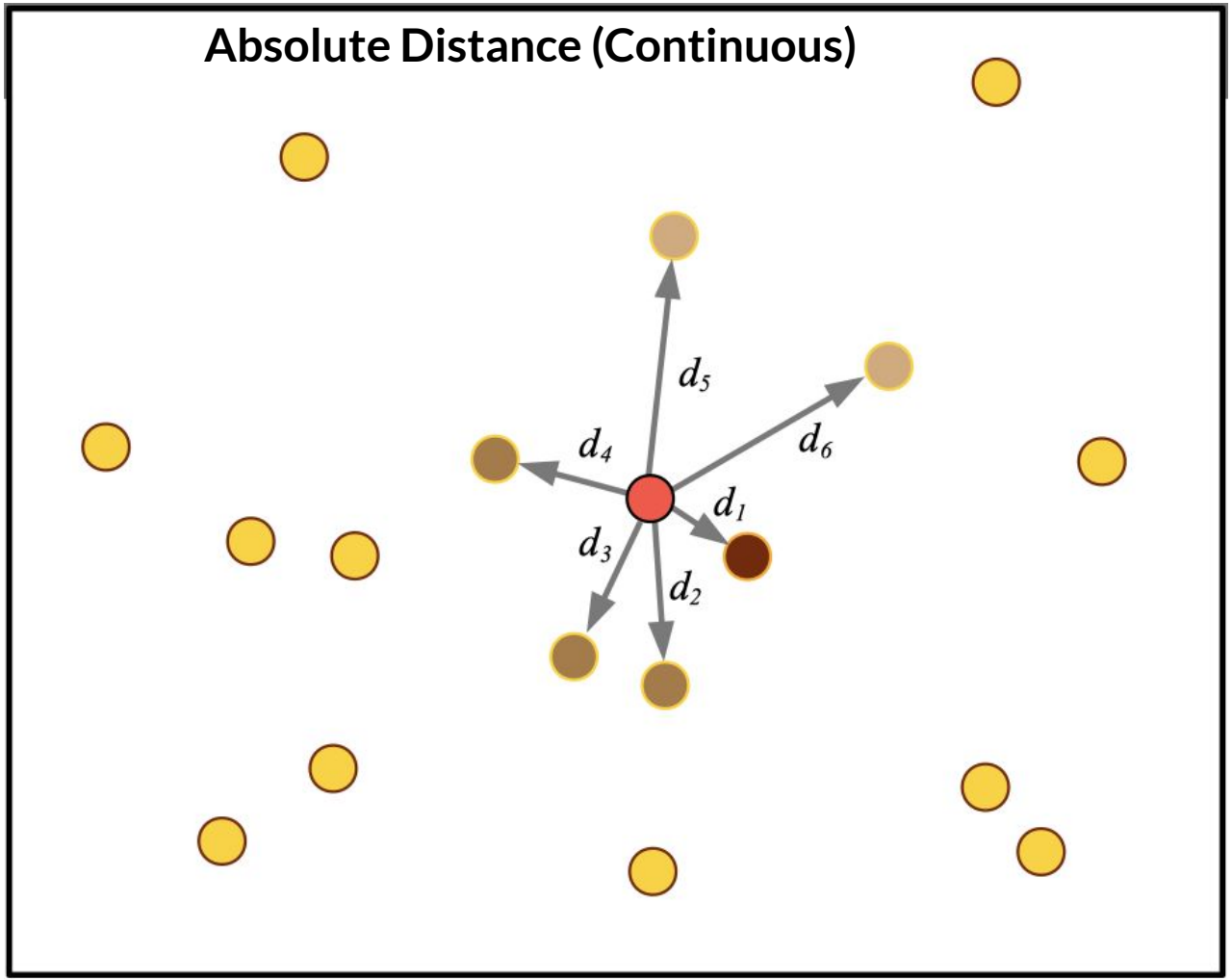
$$w_{i,j} = \frac{1}{d_{i,j}^{x}}$$

wi,j = Weight value in neighborhood weight matrix for observation *i* to observation *j*
di,j = Distance from observation *i* to observation *j*
x = Distance effect parameter

  - Examples (which one would make sense for continuous distance)
    - People within 1 km of a polluting site
    - Children with 5 km of a school
    - All grocery stores within my walking distance
    - Others ?

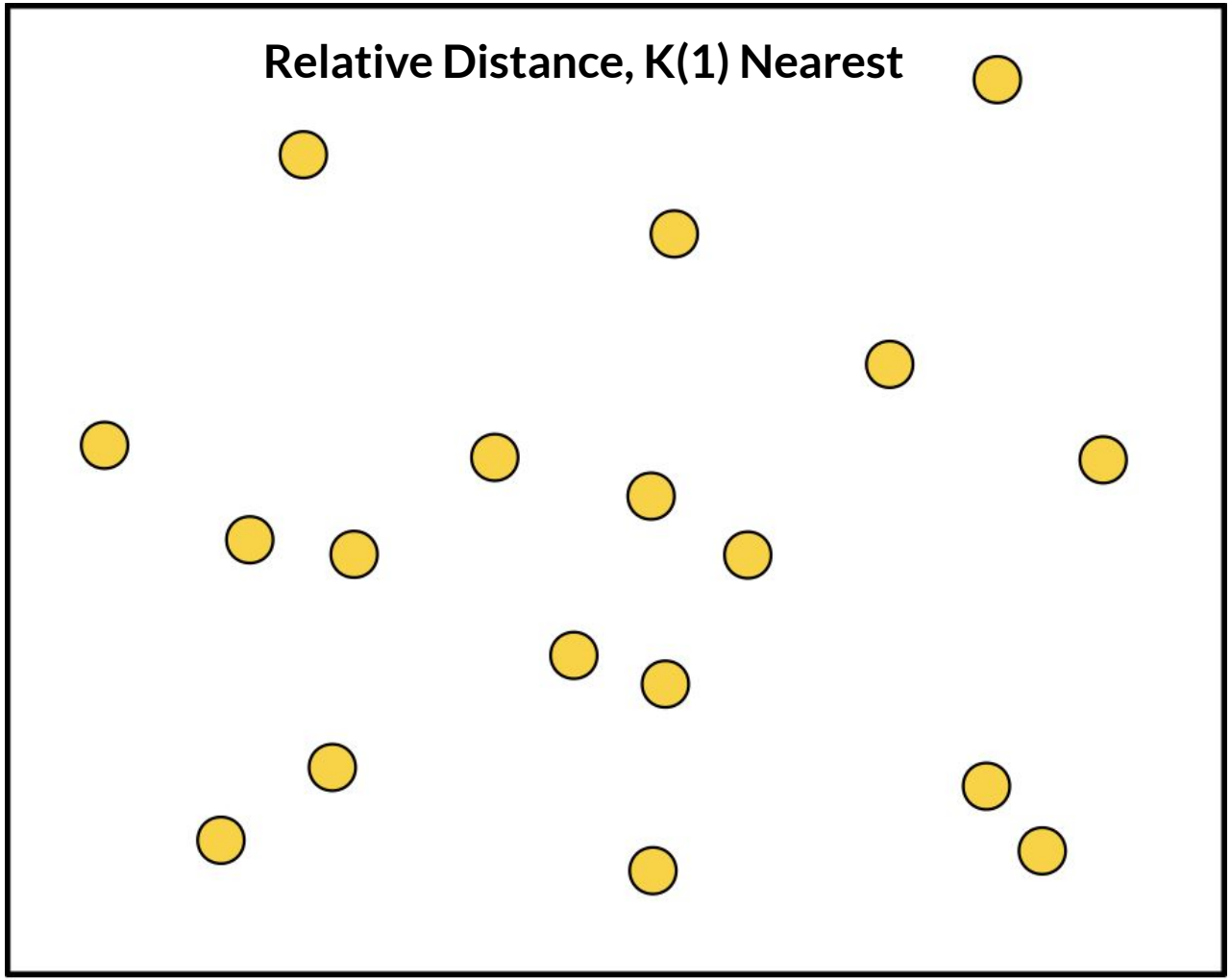

Absolute Distance (Continuous)

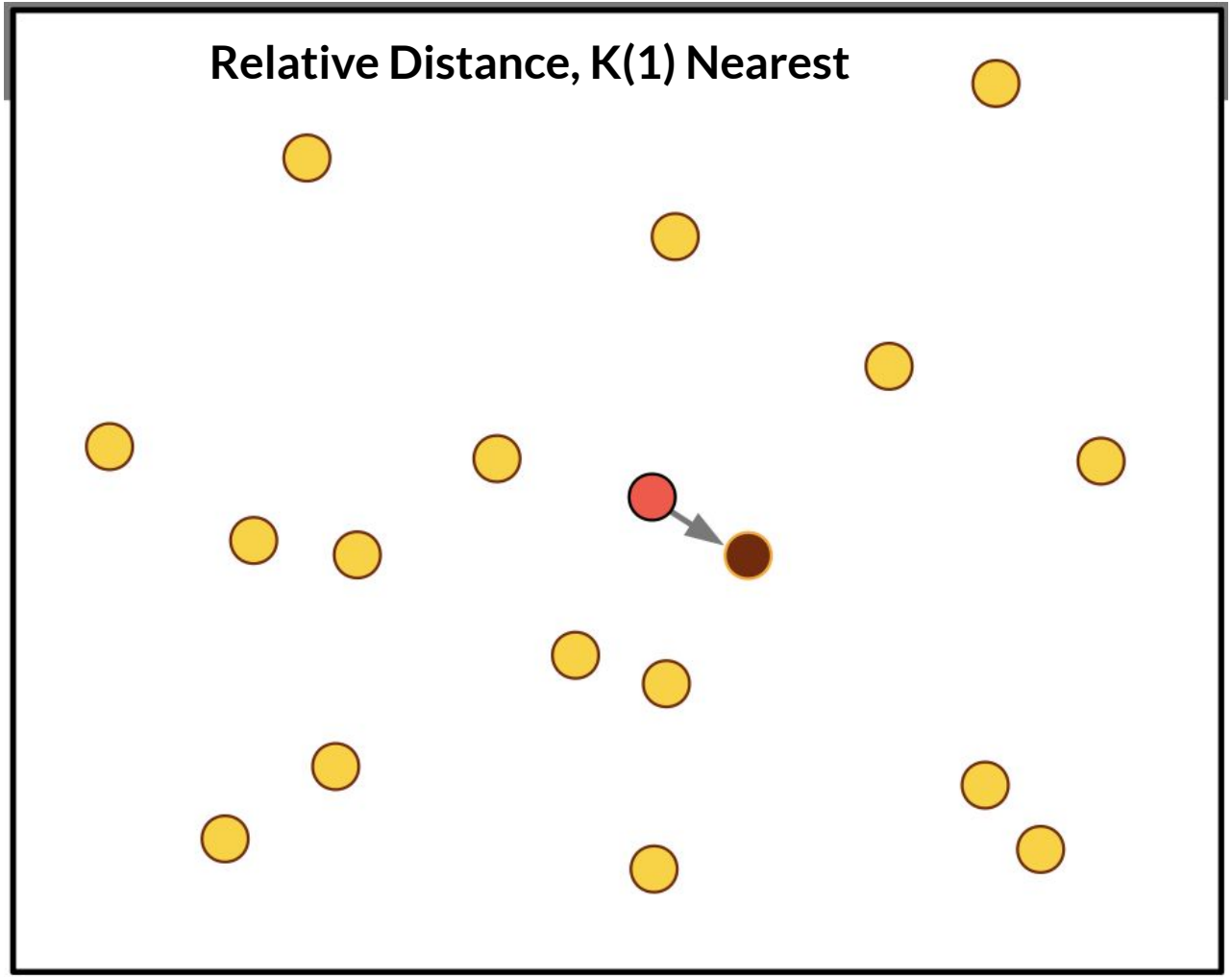
Absolute Distance (Continuous)



Neighbors

- Relative distance approach
  - Nearest feature
  - For points
    - Distance between points
  - For polygons
    - Distance between polygon centroids


Relative Distance, K(1) Nearest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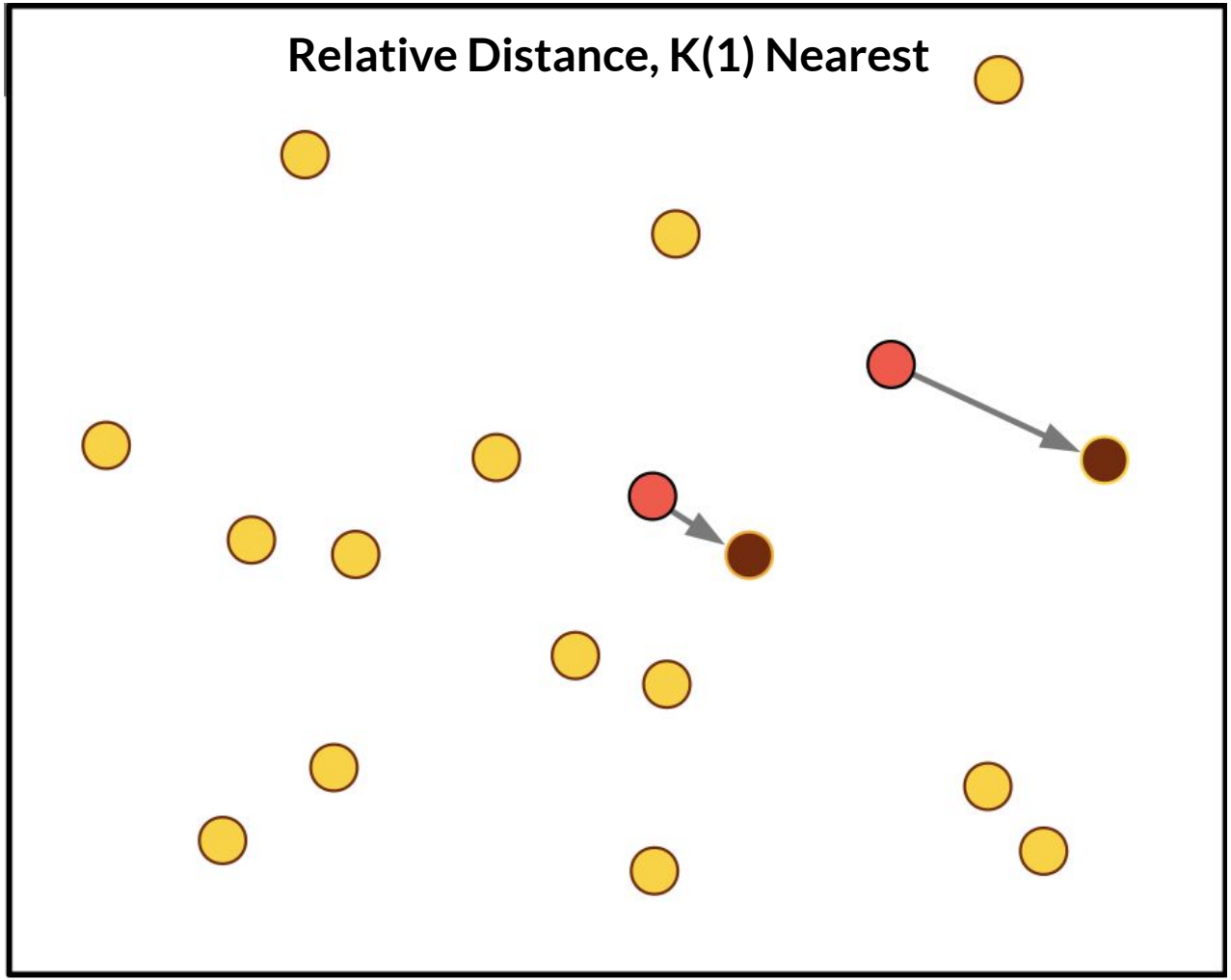
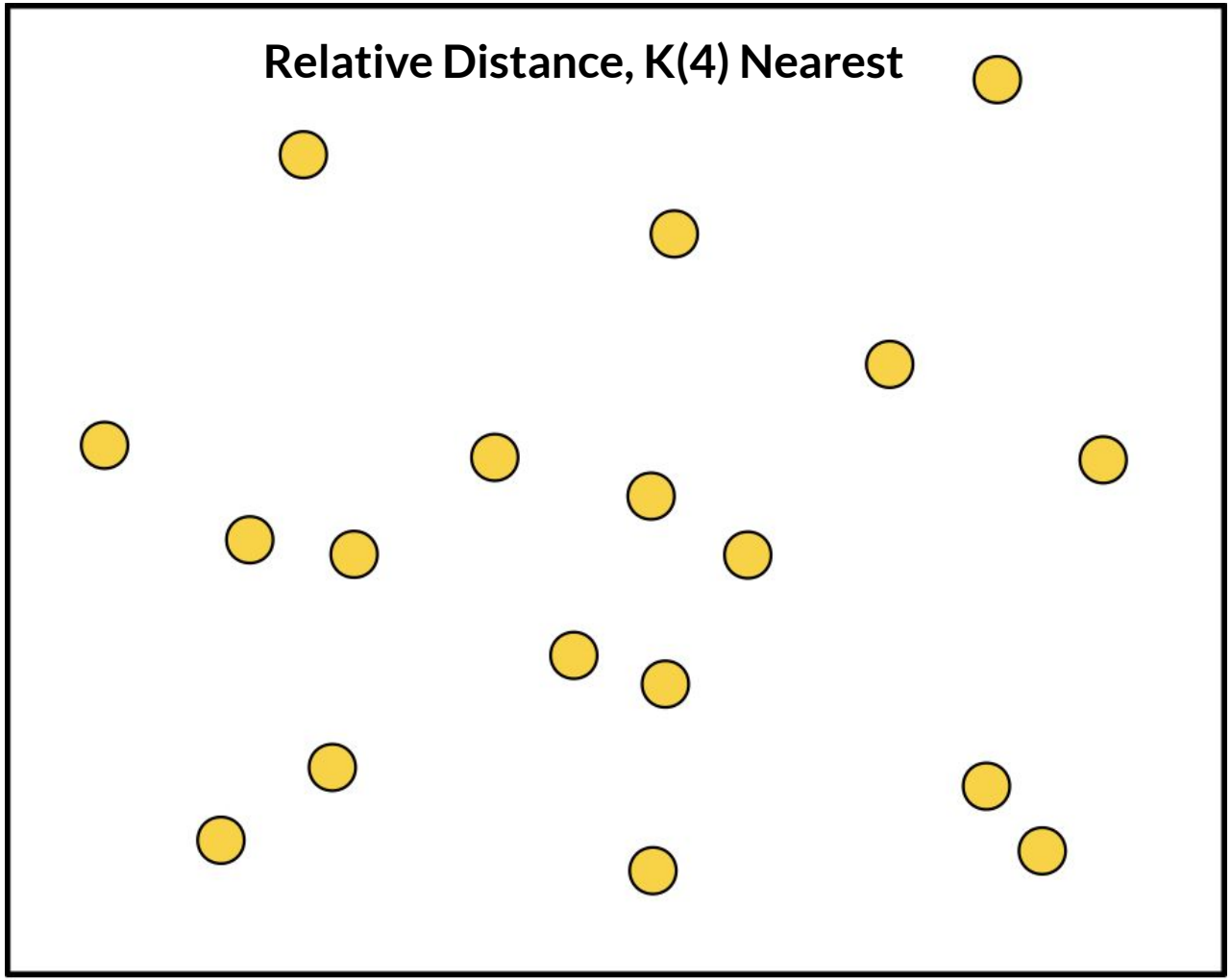
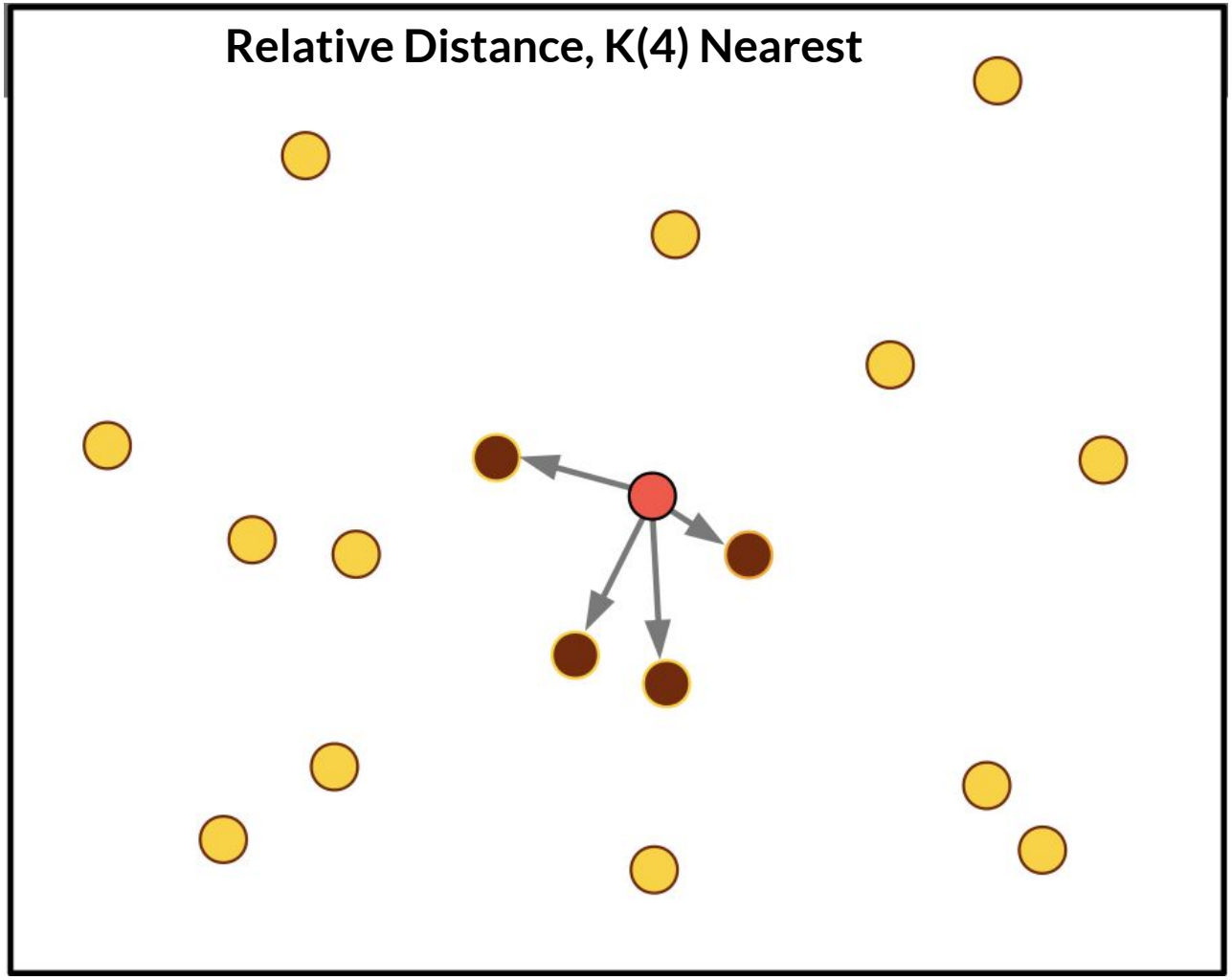
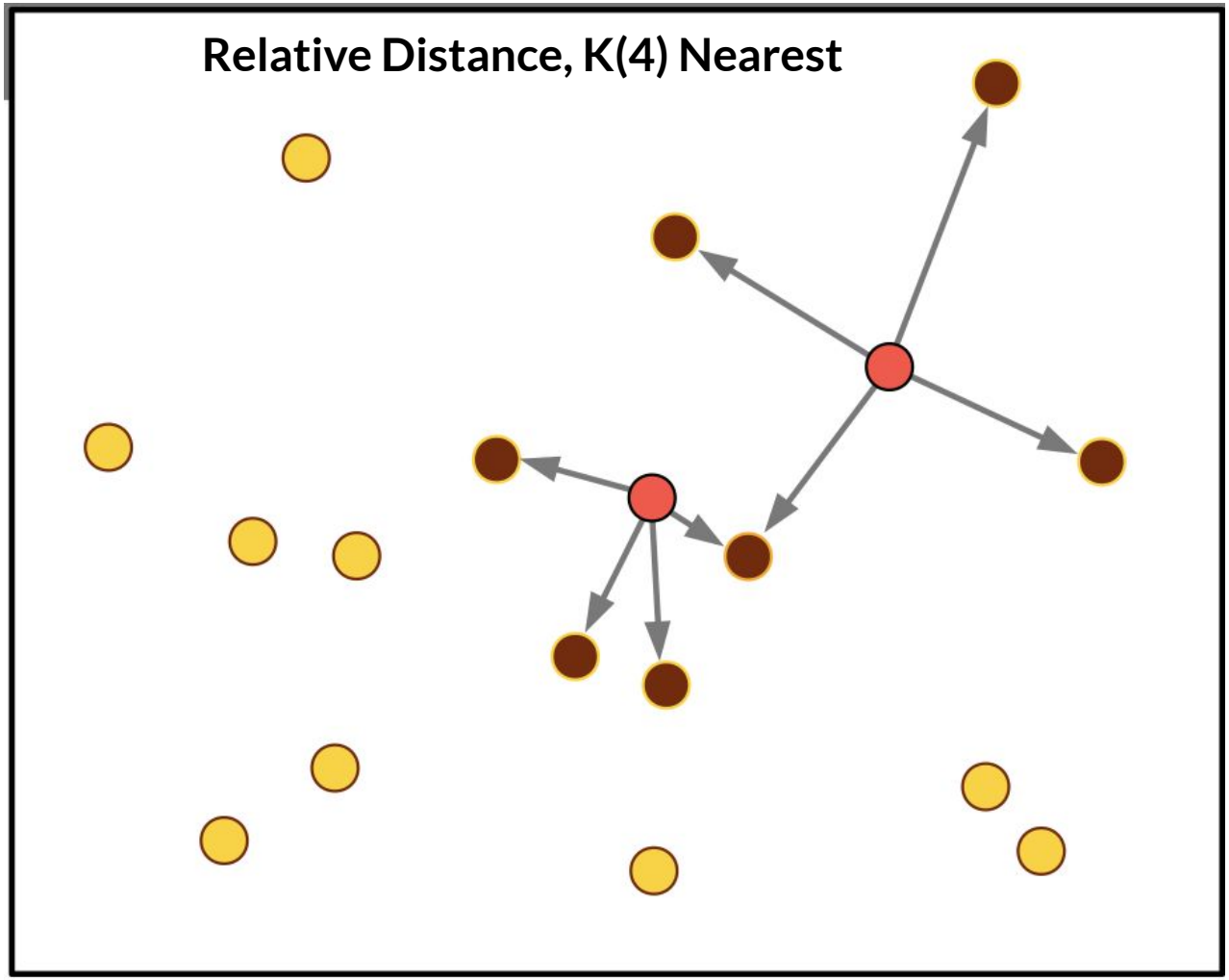

Relative Distance, K(1) Nearest


Relative Distance, K(4) Nearest

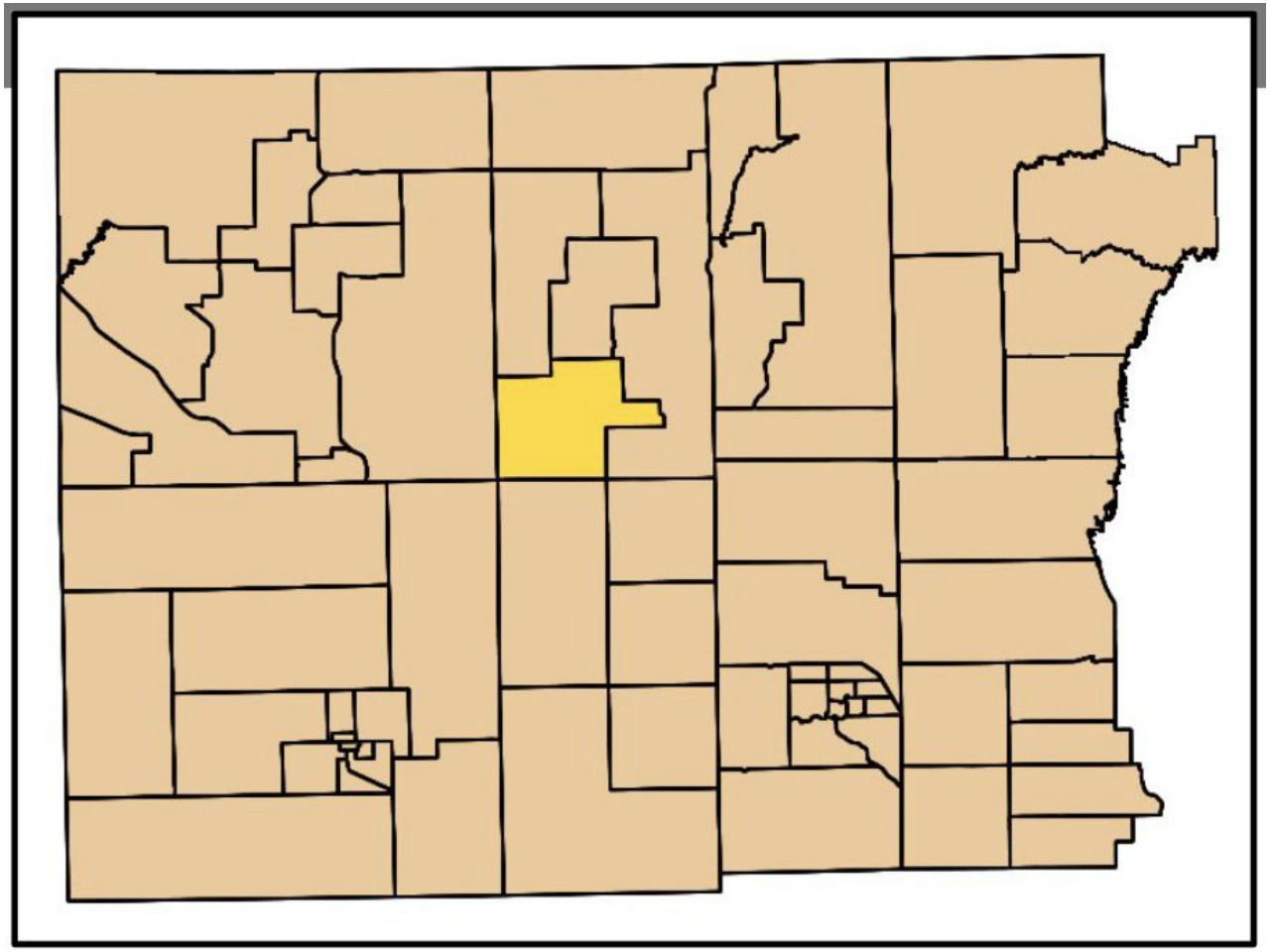

Relative Distance, K(4) Nearest


Relative Distance, K(4) Nearest

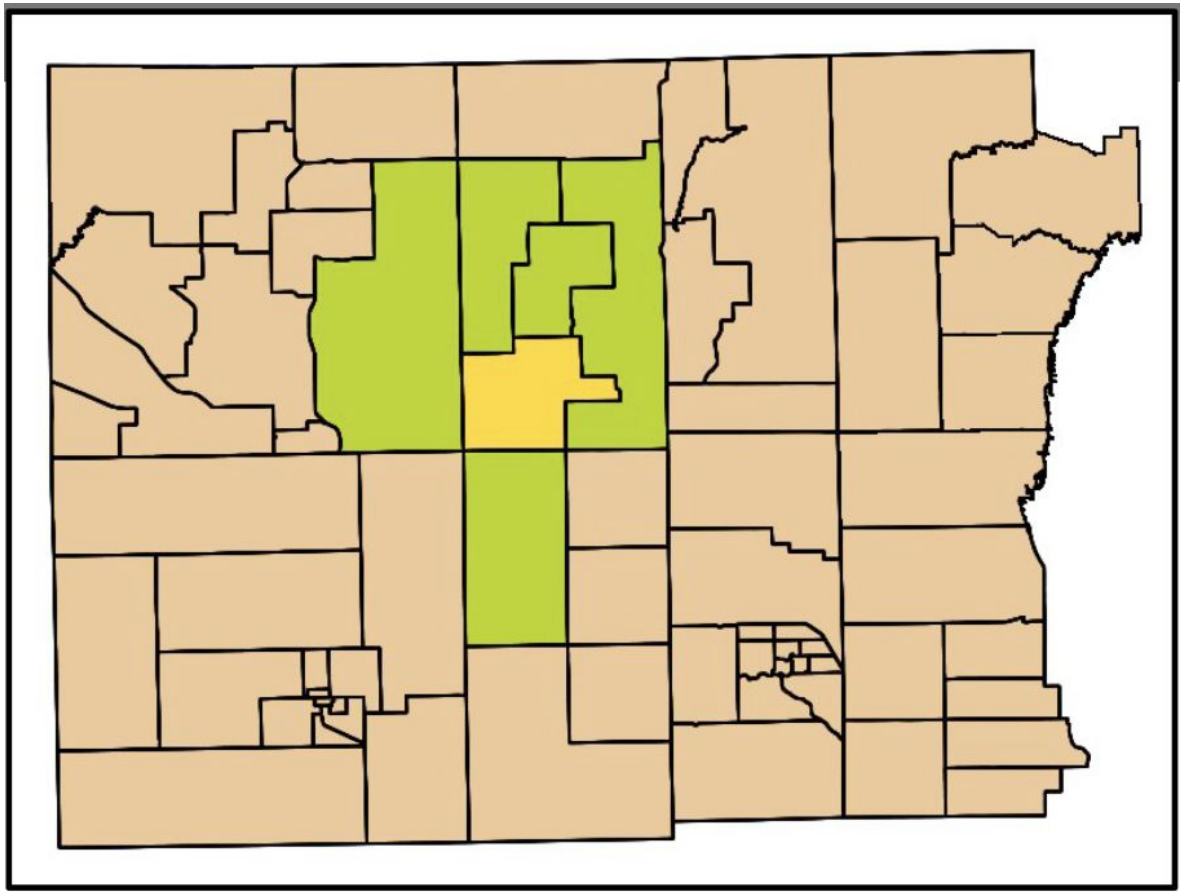
Neighbors

- Relative distance approach
  - Topology-based
  - For points
    - Not available
  - For polygons
    - Based on shared borders
    - Queen connectivity
    - Rook connectivity

Relative Distance, Topology

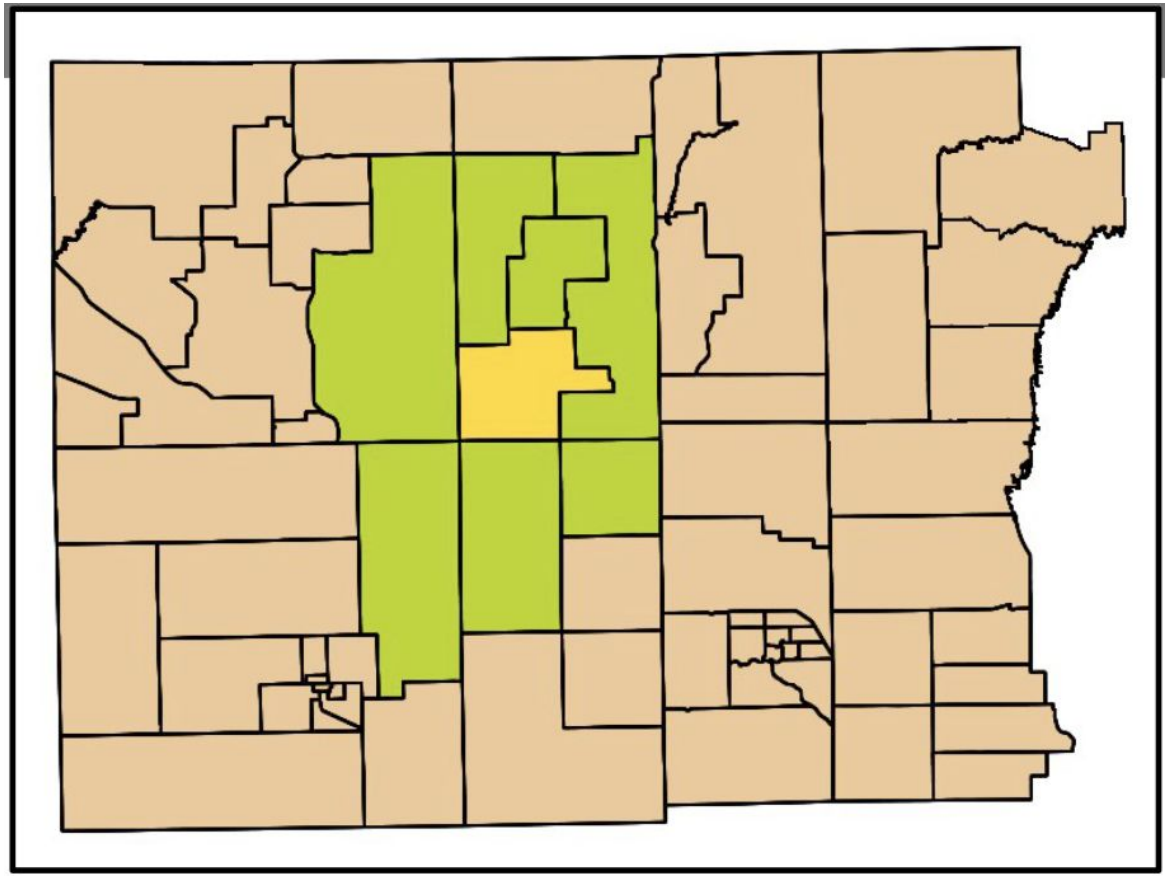


Relative Distance, Topology



Rook's case, 1st order neighbors

Relative Distance, Topology



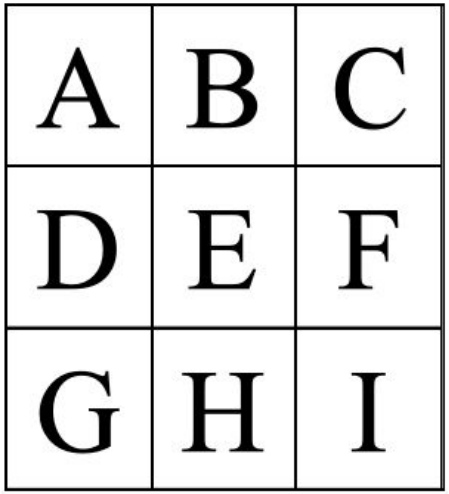
Queen's case, 1st order neighbors

Neighbors

- Stored in a neighborhood weight matrix
  - ...or, a similar format
- Matrix is a table with *n* rows and *n* columns
  - The number of observations = *n*
  - Entries in this table describe the neighbor relationships between observations

Neighborhood Weight Matrix

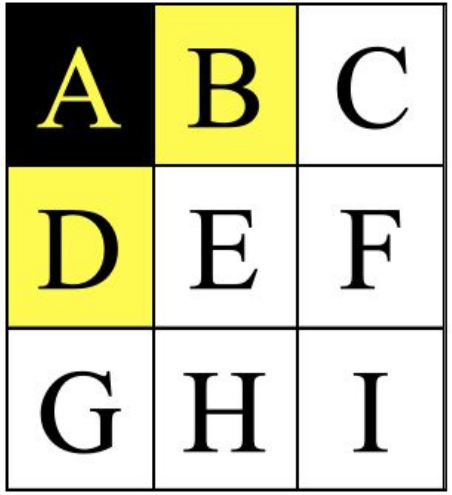
	A	B	C	D	E	F	G	H	I
A	0	1	0	1	0	0	0	0	0
B	1	0	1	0	1	0	0	0	0
C	0	1	0	0	0	1	0	0	0
D	1	0	0	0	1	0	1	0	0
E	0	1	0	1	0	1	0	1	0
F	0	0	1	0	1	0	0	0	1
G	0	0	0	1	0	0	0	1	0
H	0	0	0	0	1	0	1	0	1
I	0	0	0	0	0	1	0	1	0



Rook Contiguity

Neighborhood Weight Matrix

	A	B	C	D	E	F	G	H	I
A	0	1	0	1	0	0	0	0	0
B	1	0	1	0	1	0	0	0	0
C	0	1	0	0	0	1	0	0	0
D	1	0	0	0	1	0	1	0	0
E	0	1	0	1	0	1	0	1	0
F	0	0	1	0	1	0	0	0	1
G	0	0	0	1	0	0	0	1	0
H	0	0	0	0	1	0	1	0	1
I	0	0	0	0	0	1	0	1	0



Rook Contiguity

Neighborhood Weight Matrix

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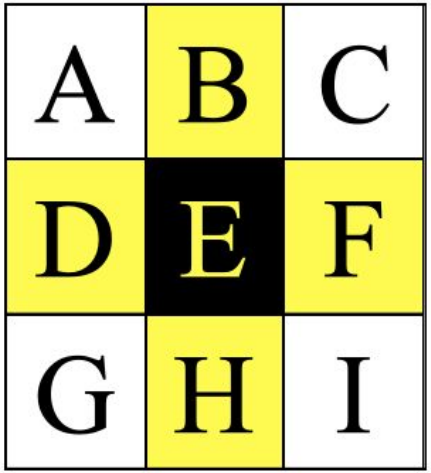
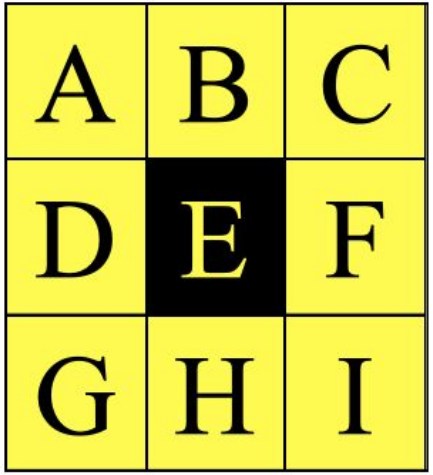
C	0	1	0	0	0	1	0	0	0
D	1	0	0	0	1	0	1	0	0
E	0	1	0	1	0	1	0	1	0
F	0	0	1	0	1	0	0	0	1
G	0	0	0	1	0	0	0	1	0
H	0	0	0	0	1	0	1	0	1
I	0	0	0	0	0	1	0	1	0



Rook Contiguity

Neighborhood Weight Matrix

	A	B	C	D	E	F	G	H	I
A	0	1	0	1	1	0	0	0	0
B	1	0	1	1	1	1	0	0	0
C	0	1	0	0	1	1	0	0	0
D	1	1	0	0	1	0	1	1	0
E	1	1	1	1	0	1	1	1	1
F	0	1	1	0	1	0	0	1	1
G	0	0	0	1	1	0	0	1	0
H	0	0	0	1	1	1	1	0	1
I	0	0	0	0	1	1	0	1	0



Queen Contiguity

Neighborhoods

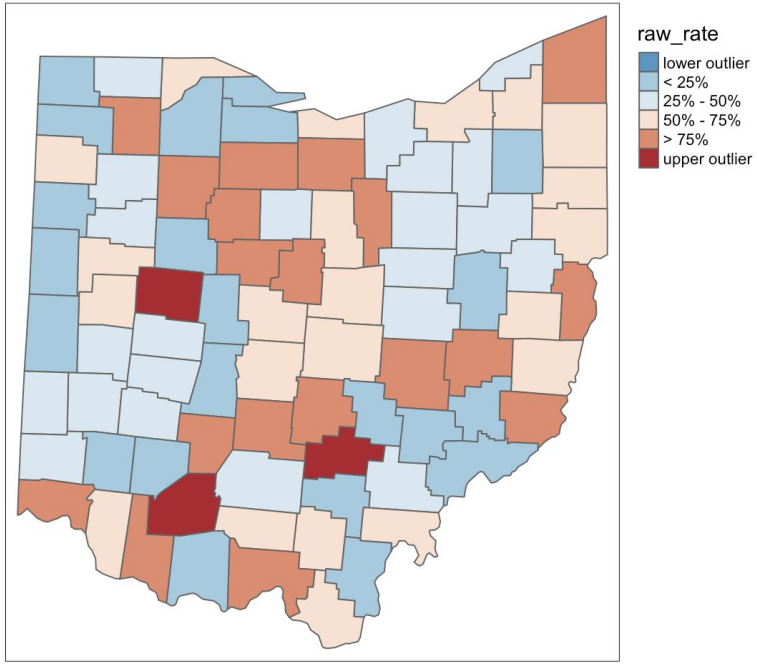
- How do I decide how to define my neighborhood?... and how to weigh my neighbors?
  - Unfortunately, no simple answer to this question
    - Theory-driven approach
      - Cite previous literature
  - Empirical approach
    - Rules of thumb: not good
    - **ESDA**: explore, optimize

Interactive Visualization

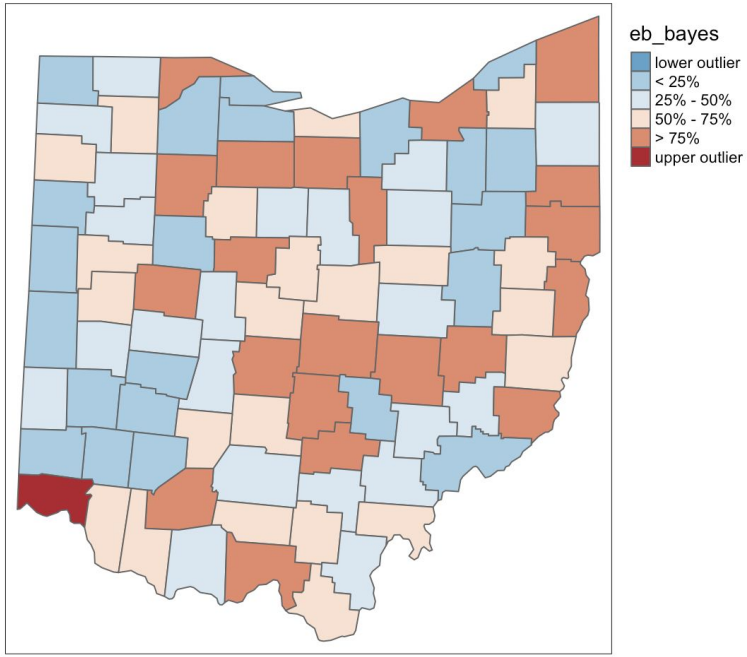
https://walkerke.github.io/2016/07/spatial-neighbors-in-r---an-interactive-illustration/

You may also want to think about neighborhoods to create better maps

Raw rate of lung cancer in Ohio



Smoothed Rate of Lung cancer in Ohio



https://spatialanalysis.github.io/lab_tutorials/Rate_mapping.html

Neighborhoods

- Exploratory Spatial Data Analysis
  - Explore your data!
    - Choose a spatial autocorrelation metric
      - (Next week!)
    - Test the metric over multiple neighborhood definitions
    - Test the metric over multiple neighborhood parameters
  - Results will likely be semi-consistent
    - Can become part of the analysis!

Neighborhoods

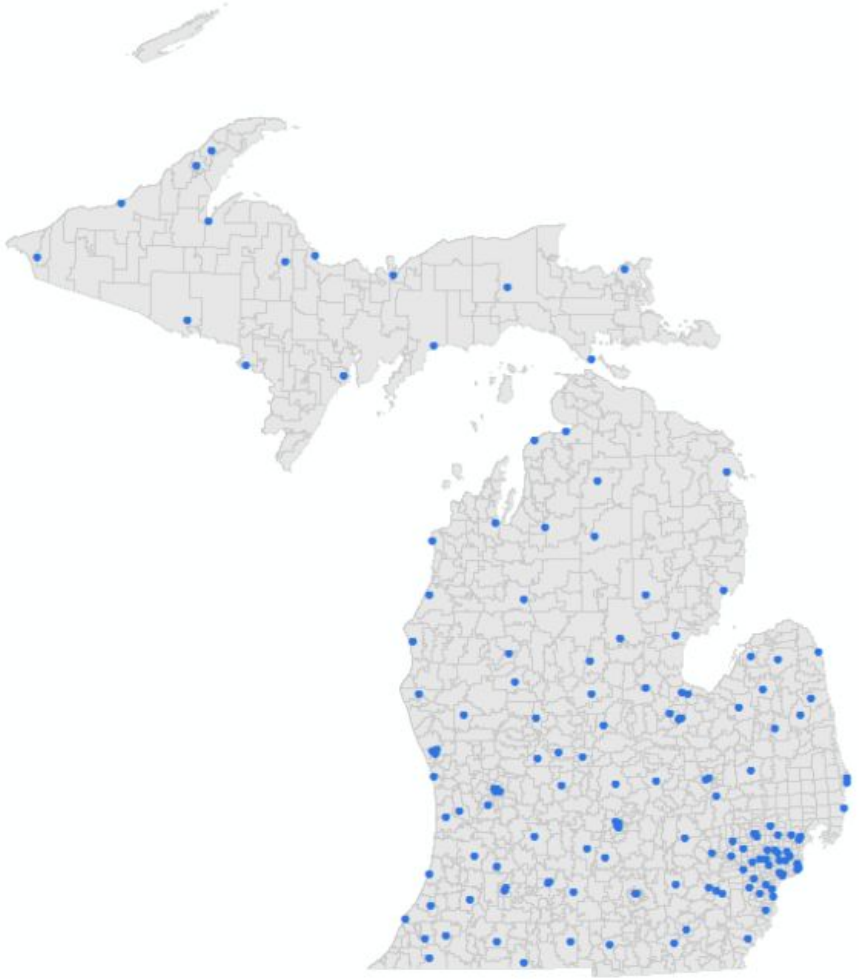
- Entries in the neighborhood weight matrix describe the relationships between observations
  - These do not have to be based on geographic relationships!
    - e.g., network connectivity
    - e.g., sociodemographic similarity
  - Construct your own matrix in R!

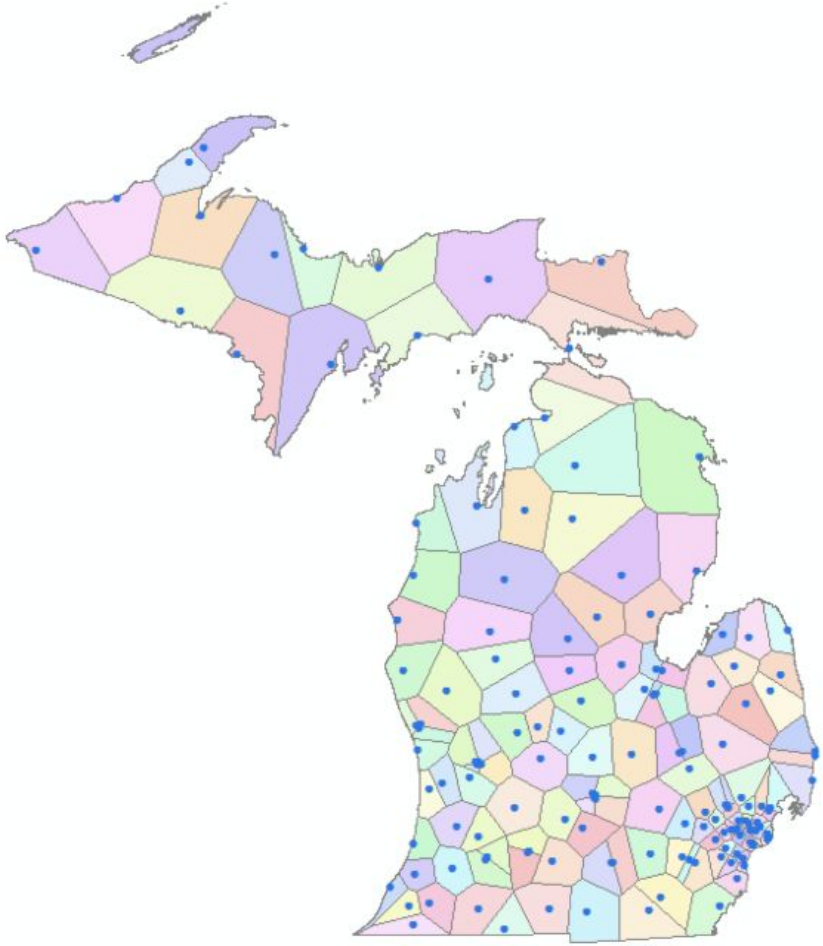
Thiessen Polygons

- Vector-based regions (neighborhoods)
  - Based on Euclidean distance
  - Nearest region to a point location
    - Based on relative measure of distance
- Start with a set of points
  - Creates a new polygon for each input point
    - Observations within each polygon are assigned to the point to which they are nearest
    - Nearest point defines “neighborhood” membership

Thiessen Polygons

- Requires two steps
  - Create Thiessen polygons from points
  - Spatially overlay other data data
    - If observations are points, easy
    - If observations are lines or polygons, requires some decisions about assignment





Connectivity

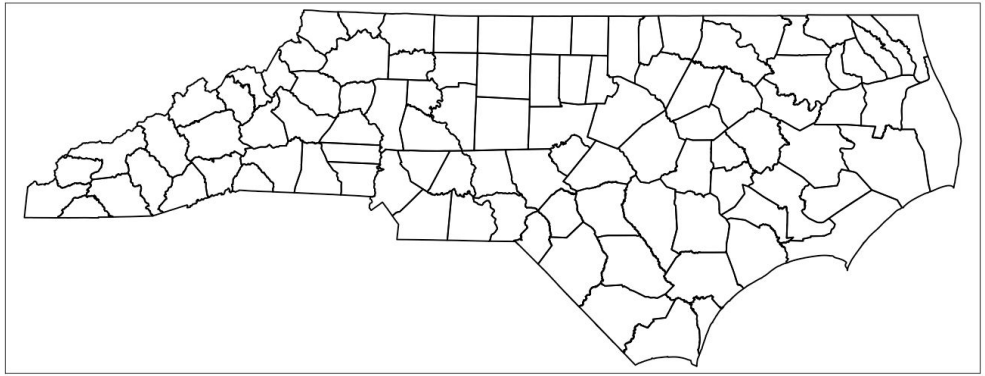
- Number of neighbors for each feature
  - Some neighborhood definitions are explicit, e.g., K nearest neighbors
    - Every feature has K neighbors!
  - Others allow this to vary
    - Absolute distance based
    - Connectivity/topology

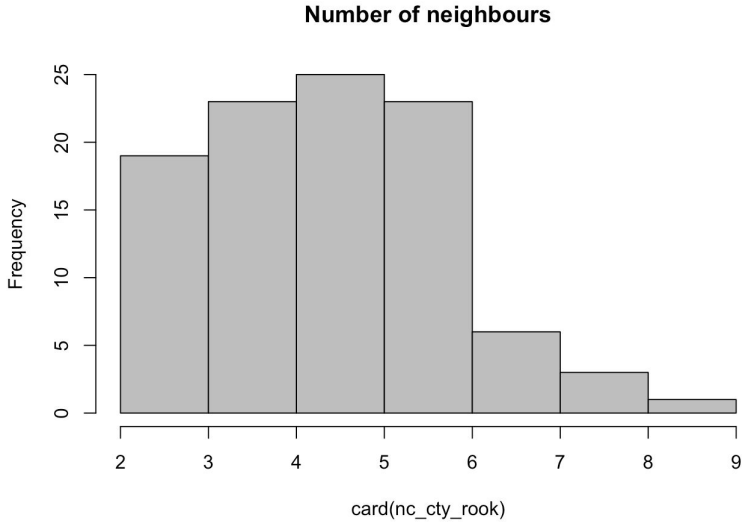
Connectivity

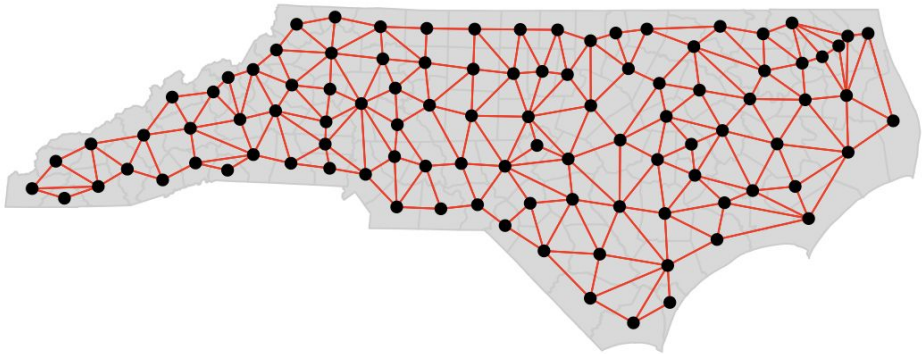
- Some interest in understanding the nature of the neighborhood connections
  - Instead of using the neighborhoods as part of the analysis, the neighborhoods become focus of the analysis
    - e.g., question may become which regions are the most connected to others?... which are least connected?... what is the distribution?
    - Contact tracing during coronavirus pandemic - Who's at most risk?
    - Others ?

Connectivity

- Tools to examine and evaluate neighborhood connectivity
  - Histogram
    - Number of neighbors on X axis, frequency on Y axis
  - Connectivity map
    - Neighborhood connections are mapped as lines connecting polygons
    - Example on next slide




Number of neighbours
Frequency
0
5
10
15
20
25
2
3
4
5
6
7
8
9
card(nc_cty_rook)



Start thinking about applications of these to your final projects

Next Class

- Spatial Clustering
- Complete lab 4
- Submit Project Proposals if you havent
- Play with:
  - https://walkerke.github.io/2016/07/spatial-neighbors-in-r---an-interactive-illustration/
- Lab 5 on spatial neighborhoods and clustering distributed on Saturday