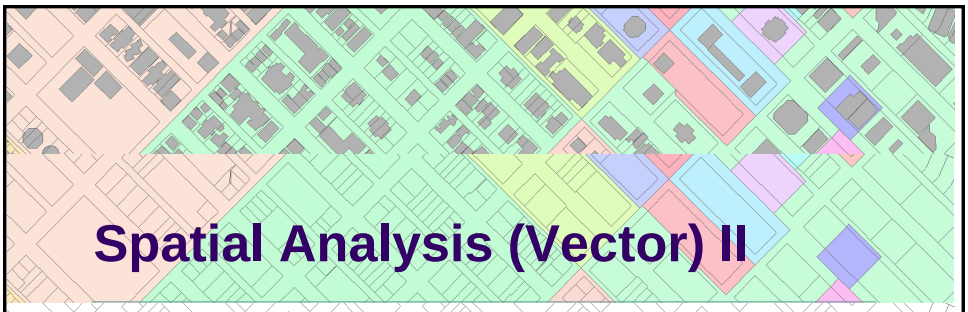

Spatial Analysis (Vector) II

GEOG 300, Lecture 9

Dr. Anthony Jjumba

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- Overview
  - Network Analysis
  - Point Pattern Analysis
  - Density Analysis
  - Spatial Interpolation
  - Geocoding

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Network Analysis

- A Spatial Network
  - is “a set of geographic locations interconnected in a system by a number of routes”
  - is a system of linear features that has appropriate attribute for the flow of objects
- A spatial network may be reduced to a topological graph.
- A connectivity matrix represents the interconnections between the **nodes** and **edges**

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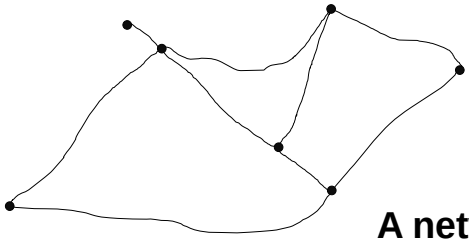
Network Analysis



Spatial Network

A network is topology-based

- Lines meet at intersections
- Lines cannot have gaps
- Lines have directions

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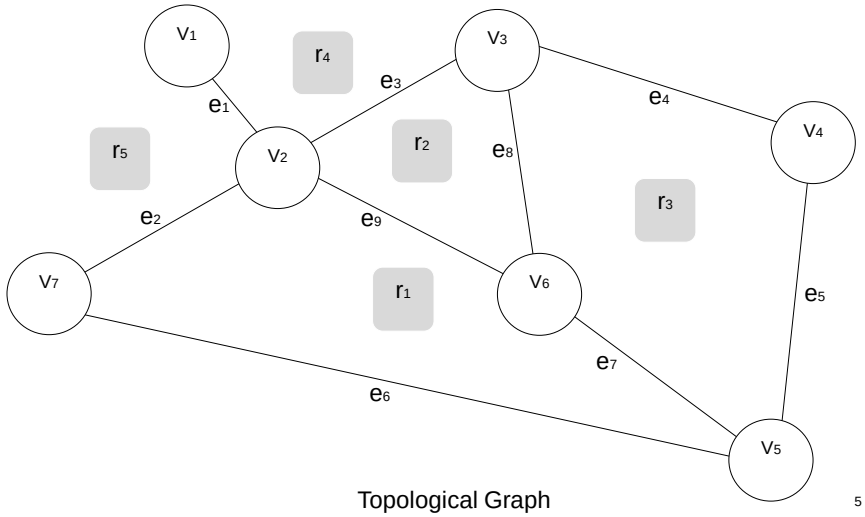
Network Analysis



Topological Graph

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Network Analysis

	Vertices(v)								Regions(r)						Edges(e)								
	1	2	3	4	5	6	7		1	2	3	4	5		1	2	3	4	5	6	7	8	9
1	0	1	0	0	0	0	0	1	0	1	1	0	1	1	0	1	1	0	0	0	0	0	1
2	1	0	1	0	0	1	1	2	1	0	1	1	0	2	1	0	1	0	0	1	0	0	1
3	0	1	0	1	0	1	0	3	1	1	0	0	0	3	1	1	0	1	0	0	0	1	1
4	0	0	1	0	1	0	0	4	0	1	0	0	1	4	0	0	1	0	1	0	0	1	0
5	0	0	0	1	0	1	1	5	1	0	0	1	0	5	0	0	0	1	0	1	1	0	0
6	0	1	1	0	1	0	0							6	0	1	0	0	0	0	1	0	0
7	0	1	0	0	1	0	0							7	0	0	0	0	1	1	0	1	1
														8	0	0	1	1	0	0	1	0	1
														9	1	1	1	0	0	0	1	1	0

0 = Not connected; 1 = Connected

Connectivity Matrices

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Network Analysis

- A GIS can find the shortest route between two nodes on a network
  - A user can control the route by selecting specific nodes the route must pass through
- Attributes of the edges represent **impedance**
  - Impendence is the amount of resistance (or cost) when traversing along the network
  - Examples of Impedance
    - Length of the edge (distance or travel time)
    - Turn Impedance
      - A turn is a transition from one edge to another
      - Turn impedance is directional

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Network Analysis

- In ArcGIS network analysis, there are four types of operations that can be performed using route finding algorithms
  - Finding a shortest route between point locations
  - Determining the service area for a facility
  - Finding the closest facility across the network
  - Creating an origin–destination matrix

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Network Analysis

- Shortest route
  - Starts with impendence matrix
  - Shortest route may be represented by distance or travel time
  - Commonly uses the Dijkstra algorithm
    - Problems
      - Traveling salesman problem
        - Visits each stop, can start anywhere, must return to origin
      - Vehicle routing problem
        - Given a fleet of vehicles and customers, minimise travel time for each vehicle

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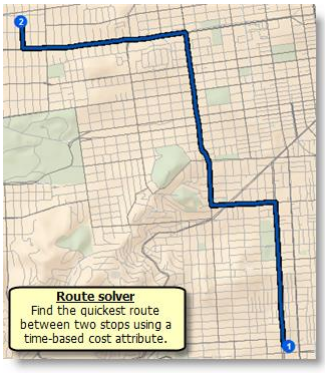
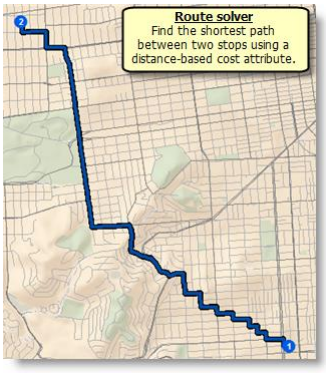
Network Analysis





Source: ESRI

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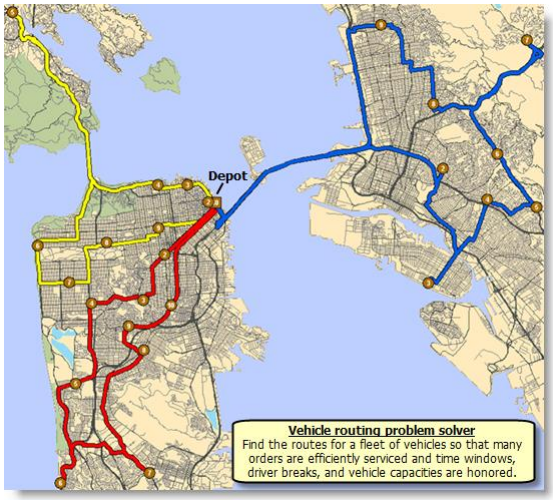
Network Analysis



Source: ESRI

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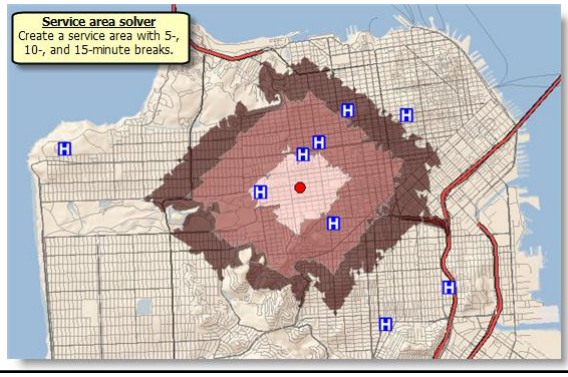
Network Analysis

- A service area for a facility
  - A region that encompasses all accessible locations with a specified impedance (isochrones). E.g. 5min service area



12

Source: ESRI

Network Analysis

- Location-allocation
  - find the shortest path from the facility to demand points on the network
  - allocating demand points to their nearest facility
  - Some ESRI application examples:
    - Given a set of existing fire stations, which site for a new fire station would provide the best response times for the community?
    - If a retail company has to downsize, which stores should it close to maintain the most overall demand?
    - Where should a factory be built to minimize the distance to distribution centers?

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Network Analysis

Source: ESRI

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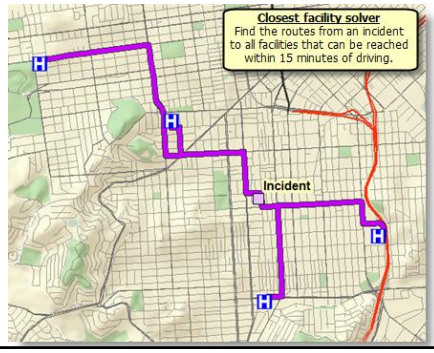
Network Analysis

- The closest facility for a location
  - find the shortest path from the location to each possible (candidate) facility
  - choose the shortest of these solutions.



Source: ESRI

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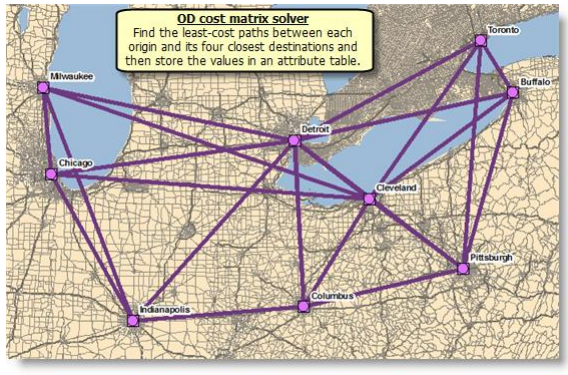
Network Analysis

- An origin–destination matrix is table of shortest paths between all origins and destinations



Source: ESRI

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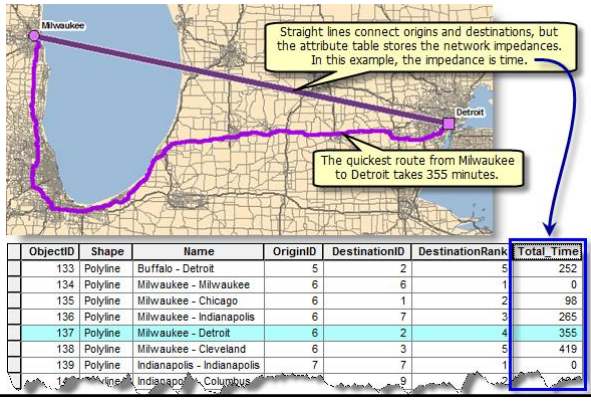
Network Analysis

- An origin–destination matrix is table of shortest paths between all origins and destinations



ObjectID	Shape	Name	OriginID	DestinationID	DestinationRank	Total_Time
133	Polyline	Buffalo - Detroit	5	2	5	252
134	Polyline	Milwaukee - Milwaukee	6	6	1	0
135	Polyline	Milwaukee - Chicago	6	1	2	98
136	Polyline	Milwaukee - Indianapolis	6	7	3	265
137	Polyline	Milwaukee - Detroit	6	2	4	355
138	Polyline	Milwaukee - Cleveland	6	3	5	419
139	Polyline	Indianapolis - Indianapolis	7	7	1	0

Source: ESRI

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Network Analysis

- Utility Networks
  - Referred to as Geometric Networks in ArcGIS
  - Examples: water distribution, electrical lines, gas pipelines, telephone services, and water flow in a stream
  - Junctions can act as **sources** or **sinks** and determine flow direction in a network
    - Flow is away from sources
    - Flow is toward sinks

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Network Analysis

- Utility Networks
  - A common type of analysis in geometric networks is **network tracing**.
    - involves placing a marker on the network and tracing either upstream, or downstream, or both.

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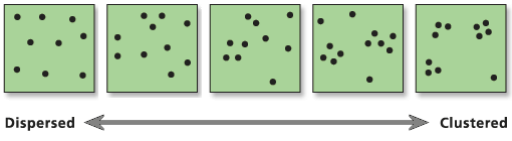
Point Pattern Analysis

- Point pattern analysis: the examination or evaluation of the pattern of distribution (spatial arrangement) for set of points.



gispopsci.org

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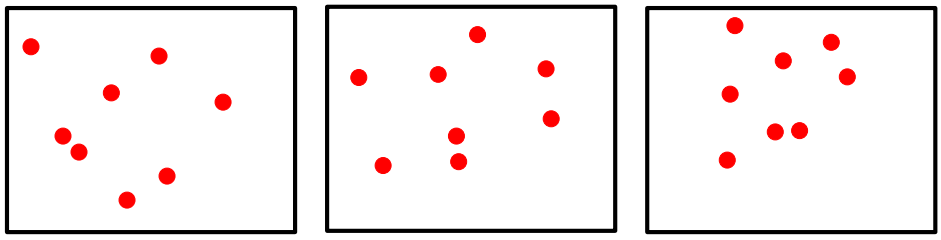
Point Pattern Analysis

- Can you tell which is one Random, Clustered or Uniformly (dispersed) distributed?



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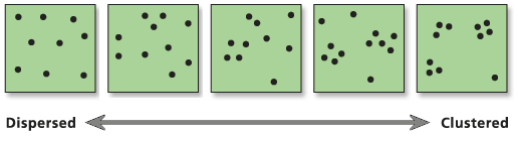
Point Pattern Analysis

- Nearest Neighbor Analysis
  - A method used to determine whether a distribution is clustered, random or regular.



ESRI

  - To assess the spacing of points, the average nearest neighbor distance is determined.

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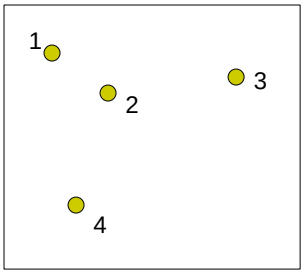
Point Pattern Analysis

- Nearest Neighbor Analysis



$d_1 = l_{12}$
$d_2 = l_{21}$
$d_3 = l_{32}$
$d_4 = l_{42}$

$$r_{obs} = \frac{\sum d_i}{n}$$

The Average Nearest neighbor distance = r_{obs}

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Point Pattern Analysis

- Nearest Neighbor Analysis
  - The nearest neighbor statistic is determined as a ratio of r_{obs} *to* r_{exp}, the expected average nearest neighbor distance for a random distribution

$$r_{\exp} = \frac{1}{2\sqrt{n/A}}$$

Where :
A is area of study region
n is number of points

$$R = \frac{r_{obs}}{r_{\exp}}$$

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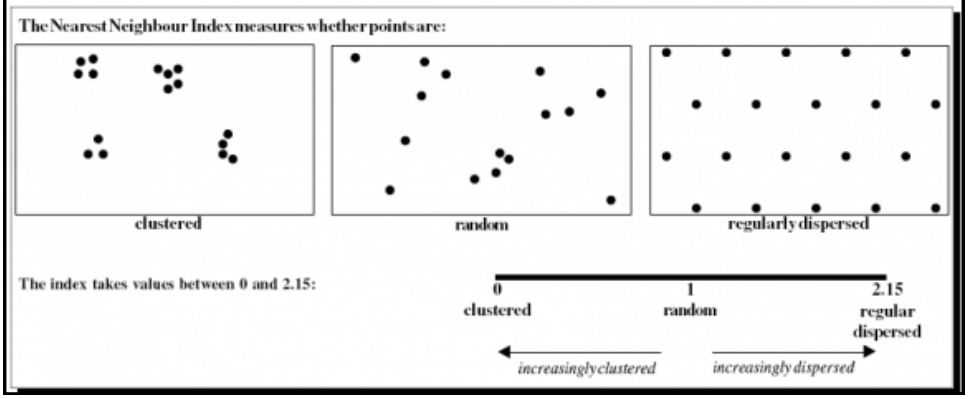
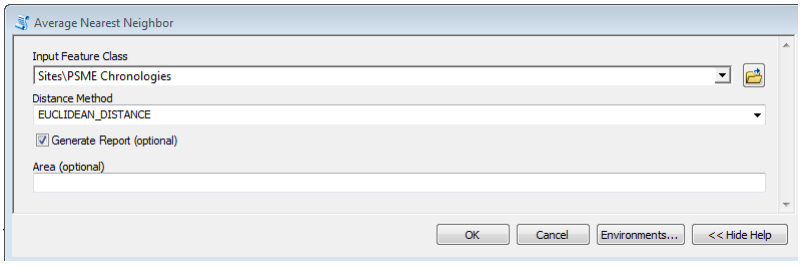
Point Pattern Analysis

- Nearest Neighbor Analysis
  - Average distance from each point to its nearest neighbor, R
  - 0 = clustered, 1 = random, 2.15 = even



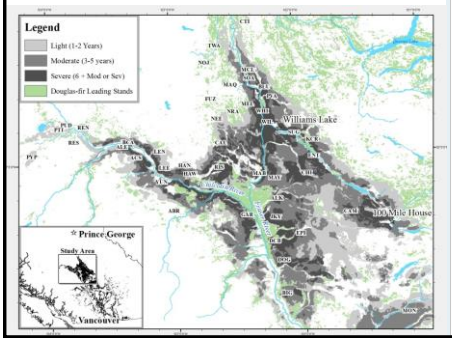
Point Pattern Analysis

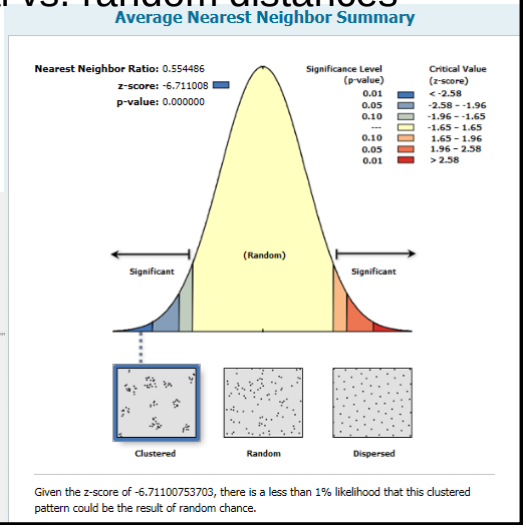
- Nearest-Neighbor Analysis in ArcGIS
  - Tool: Average Nearest Neighbor
  - Select a points layer
  - Check “Generate Report”
  - Hit OK



Results are In: Nearest Neighbor

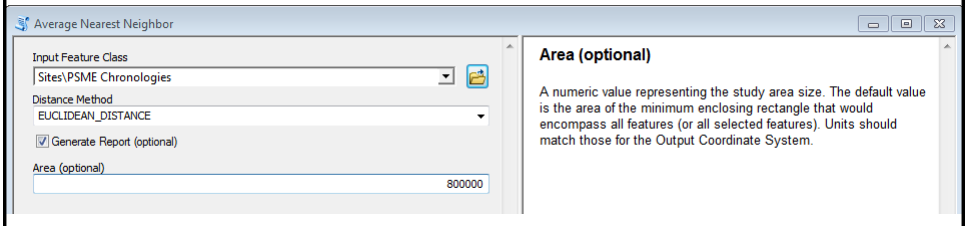
- Comparison of actual vs. random distances
  - Clustered
  - Significant
  - Why?





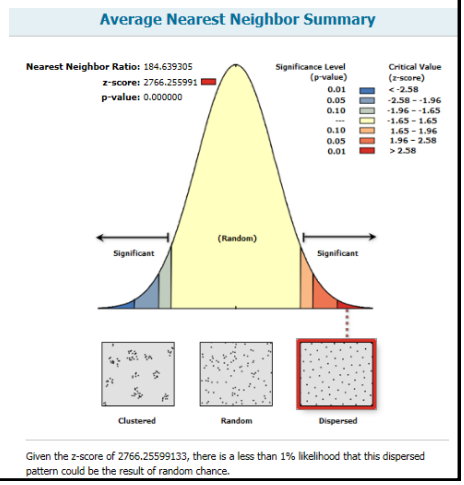
Nearest Neighbor with Defined Area

- 800,000 hectares affected by budworm
- Vs. ~4,000,000ha minimum enclosing rectangle
- Set the study area size at 800,000ha



Constrained Results are In

- Dispersed distribution
- Significant (statistically)



Density Analysis (Estimation)

- Density Analysis: The estimation of the variation of the density across a study area.
  - number of measurements per area
  - show where point or line features are concentrated
  - Point or line data to raster surface
  - E.g. Point value for each town representing the total number of people in the town, by calculating density, you can create a surface showing the predicted distribution of the population throughout the landscape.

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Density Analysis

- Three density tools in Spatial Analyst
  - Point density, line density, kernel density
  - All density tools produce new raster datasets
    - Line density
    - Point density
      - Simple density estimation: the number of points or lines that fall within the search area are summed, then divided by the search area size to get each cell's density value
      - The values in **attribute field** (e.g. population) that fall within the identified neighborhood are divided by the area of the neighborhood.

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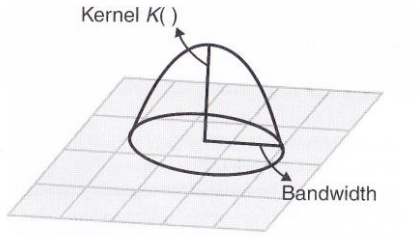
Density Analysis

- Kernel density
  - quadratic function; center of the surface is the point location and tapering to zero at the search radius distance



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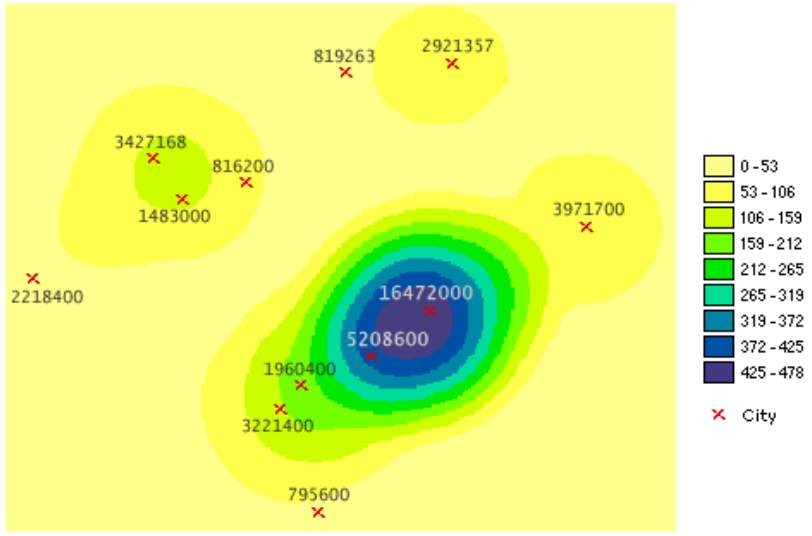

Population density surface example

SOURCE: ESRI

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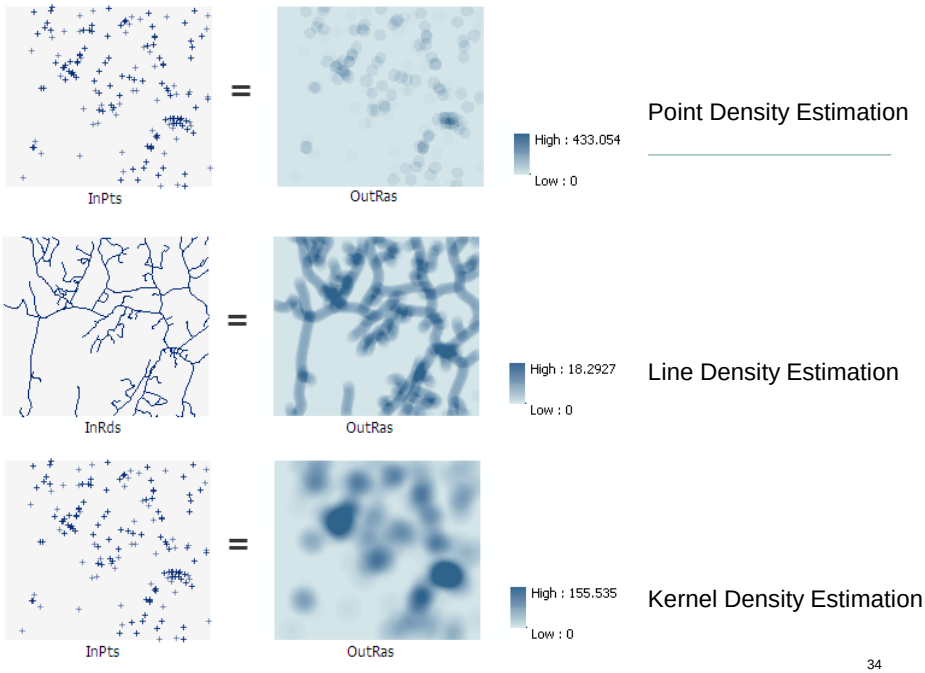

SOURCE: ESRI

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Spatial Interpolation

- Interpolation: Predicts values at unsampled locations using a set of sampled data points within the study area
- Phenomenon: continuous field
  - Methods of interpolation assume that the values measured at nearby sample points are more similar than the values measured at distant sample points(Tobler's First Law)
  - Point data to raster surface

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Spatial Interpolation

- In estimating rainfall, temperature, and other attributes at places that are not weather stations, and where no direct measurements of these variables are available.
- In estimating the elevation of the surface between the measured locations of a digital elevation model (DEM)
  - Methods: **Thiessen Polygons, Inverse Distance Weighting,** TIN**,** Thin plate splines, Kriging

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Geocoding

- Geocoding is a process of creating spatial features from textural descriptions such as addresses, place names.
  - Can be considered part of data management
- Geocoding typically uses Linear interpolation as a method to find the location information about an address.
  - If the addresses along a residential street range from 1000 to 2000, then house number = 1300 is about one-third of the way on the street

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Geocoding

- The types of text-based information can include addresses, points of interest, or place names such as mountains, bridges, and towns.
  - Addresses have to be correctly spelt (mostly correct at least)

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Geocoding

- The Geocoding Process
  - address matching is a type of geocoding that uses a street address database to identify locations of unknown addresses.
  - Two inputs:
    - a list of address records to be geocoded and
    - a reference layer based on the road network
  - The output: a point file, where each point represents an address record

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Geocoding Tutorial

- I encourage you to go through the following tutorial
  - http://help.arcgis.com/en/arcgisdesktop/10.0/pdf/geocoding-tutorial.pdf
  - http://pro.arcgis.com/en/pro-app/help/data/geocoding/tutorial-find-addresses.htm
  - The data:
    - http://www.arcgis.com/home/item.html?id=ca11a1f63e9a40c781b4071fdb7b017a

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