GIST 4302/5302: Spatial Analysis and Modeling

Lecture 2: Review of Map Projections and Intro to Spatial Analysis

Guofeng Cao

http://www.spatial.ttu.edu

Department of Geosciences
Texas Tech University

guofeng.cao@ttu.edu

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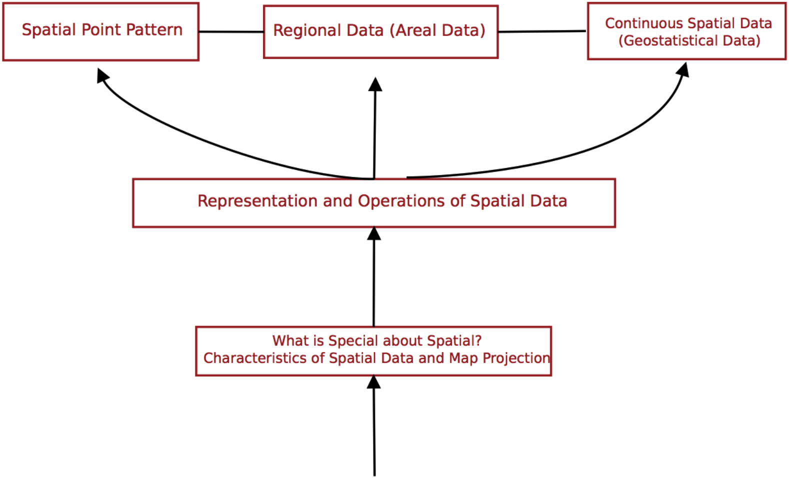
Course Outline



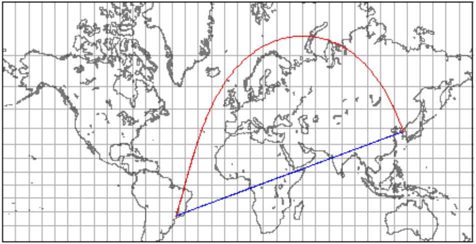
Map projections

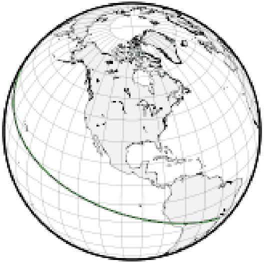
- Elements in map projections
  - Datum (e.g., WGS84$\sim$NAD 83, NAD 27)
  - Developable surfaces
  - Projection
- Distortions
  - shape (comformal), distance, area (equivalent), direction
  - distortions magnitude varies across a map
  - be careful of what you want to preserve

Great instructions on map projections: http://www.progonos.com/furuti/MapProj/CartIndex/cartIndex.html

Mercator Projection

- One of the most commonly used map projections in wall maps
- Which of the following operations is/are suitable in Mercator projection?
    1. navigation
    2. distance measuring
    3. nearest neighbors
- Why the air flight traces are not straight lines on a map?
- What would it really look like if drawing a line on a map with Mercator projection?





Distortions of Mercator Projection

- It usually leads to distortions in terms of shape and area
- Online map websites (e.g., Google Maps, ArcGIS online) use Web Mercator, a variant of Mercator projection
- Mercator puzzle: `http://hive.sewanee.edu/pridepj0/286/mercatorMap.html`

Mercator Projection

- Africa in Mercator projection

Mercator Projection

- In fact, area of Africa is about 14 times of Greenland

Mercator Projection

- In fact, Africa is as big as the United States, China, India, Japan and all of Europe combined

Figure: Image courtesy: Kai Krause

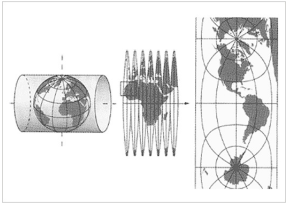
- Scene in TV show *West Wing*: `https://www.youtube.com/watch?v=n8zBC2dvERM`

Gall-Peters Projection

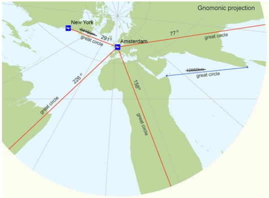
- Peters projection mentioned in the video
- Equal-area

Other Commonly Used Projections

- UTM (Universal Traverse Mercator)



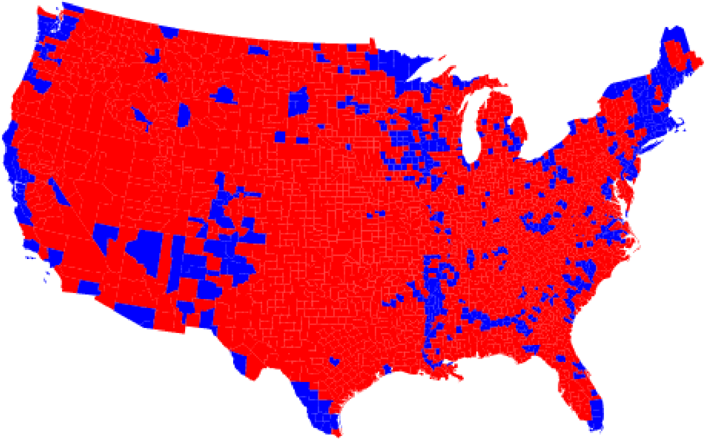
- Gnomonic (great circles as straight lines)



- Equal-area (e.g.,Lambert, Albers)

Cartogram

- County map of 2004 US presidential election result



Cartogram

- *Equal-density* cartogram of 2004 US presidential election result

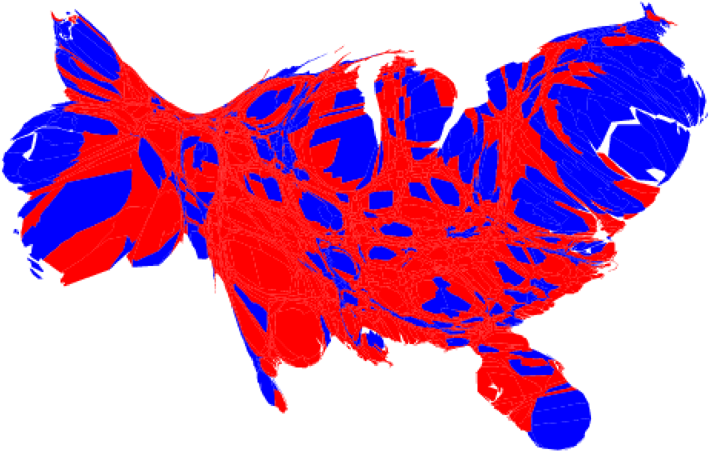


Figure: Image courtesy: Gastner, Shalizi,and Newman

Cartogram

- *Equal-density:* cartogram of world population in the year of 2000

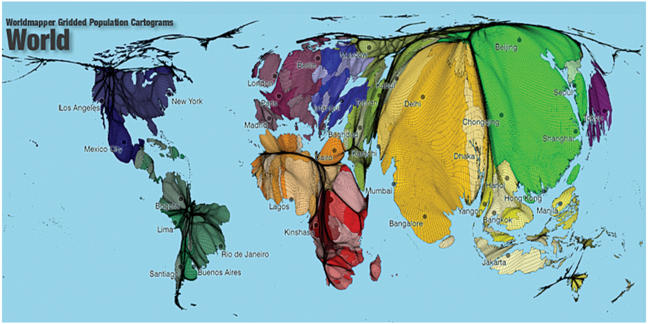


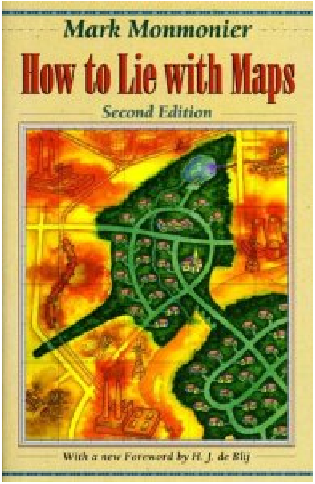
Figure: Image courtesy: ESRI

Measures and Map Projections

- Comparing results of volume measures (e.g., length and area) in different map projections http://servicesbeta.esri.com/demos/compareMeasurements.html

Maps Lie

Maps could lie, be citical when reading them!!



Introduction to Spatial Analysis and Modeling

Components of Spatial Analysis and Modeling

- Data do not equal information
- Components of spatial analysis (geospatial data in particular)
  - Visualization: Showing interesting patterns (mapping, geovisualization)
  - Exploratory spatial data analysis: Finding interesting patterns
  - Spatial modeling, regression: Explaining interesting patterns

Scope of Spatial Analysis and Modeling

- Type of spatial data analysis
  - Spatial data manipulation (in GIS)
    - Spatial query, measurements, transformation, network analysis, location analysis (spatial optimization) ...
  - Spatial data analysis
    - Exploratory spatial analysis
    - Visual analytics
    - Data-driven, let data speak themselves
  - Spatial statistics
    - An extension of traditional statistics into a spatial settings to determine whether or not data are typical or unexpected
    - Geostatistics: Quantify the spatial relationships between observations of different locations for estimation of unknown locations
  - Spatial modeling
    - Involves constructing models to predict spatial outcomes
    - Only focus on spatial statistical modeling

Topics

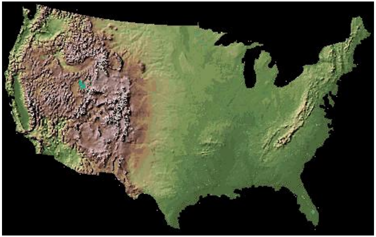
- Spatial data representation and manipulation
  - Buffer, spatial query, overlay analysis (lab 2-3)
  - Surface analysis and map algebra (lab 4)
  - Model builder (lab 5)
  - Geocoding (lab 6)
- Point pattern analysis (lab 7)
- Spatial statistics
  - Spatial autocorrelation (lab 8)
  - Spatial regression (lab 9)
- Spatial interpolation
  - Deterministic interpolation (lab 10)
  - Kriging (lab 10)
- Spatial uncertainty

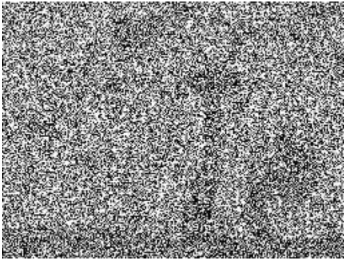
Characteristics of (Geographic) Spatial Data

1. Spatial (and temporal) Context: “Everything is related to everything else, but near things are more related than distant things”
    - Waldo Toblers First Law (TFL) of geography
    - nearby things are more similar than distant things
    - phenomena vary slowly over the Earth’s surface
    - Compare time series

Characteristics of (Geographic) Spatial Data

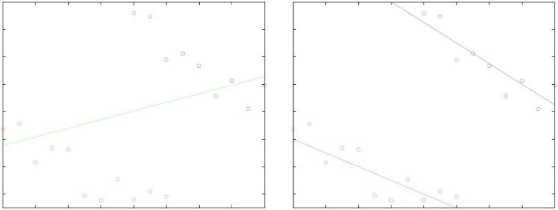
- Implication of Tobler's First Law (TFL)
  - We can do samplings and fill the gap using estimation procedures (e.g. weather stations)
  - Spatial patterns
  - Image a world without TFL:
    - White noise
    - No lines, polygons or geometry (how to draw a polygon on a white noise map?)





Characteristics of (Geographic) Spatial Data

2. Spatial heterogeneity
   - "Second law of geography" (Goodchild, UCGIS 2003)
   - Earths surface is non-stationary
   - Laws of physical sciences remain constant, virtually everything else changes
     - Elevation,
     - Climate, temperatures
     - Social conditions
   - Implications
     - Global model might be inconsistent with regional models
     - Spatial Simpsons Paradox (a special case of modified areal unit problem, which we will discuss more in the later of this class)



(a) Global Model   (b) Regional Models

Side note: example of Simpson's paradox

- Simpson's paradox usually fools us on tests of performance in real life
- The following is a real life example. Comparison of recovery rates between a new treatment and a traditional treatment for kidney stones.

	New Treatment	Traditional Treatment
Small Stones	93%(81/87)	87%(234/270)
Large Stones	73%(192/263)	69%(55/80)
All	78%(273/350)	83%(289/350)

- Comparison of batting average of two baseball players:

	1996	1997	Combined
Derek Jeter	25.0%(12/48)	31.4%(183/582)	31.0%(195/630)
David Justice	25.3%(104/411)	32.1%(45/140)	27.0%(149/551)

Characteristics of (Geographic) Spatial Data

- In a spatial settings, it is related to modified areal unit problem (MAUP) or omitted variable problem, which will discuss more in the later of this class

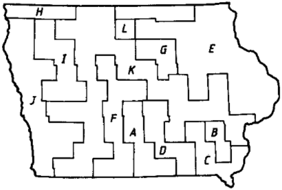


Figure 2a. Zoning system that minimises the regression slope coefficient (-24, r = -.25)

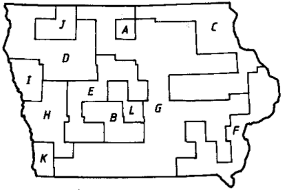


Figure 2b. Zoning system that maximises the regression slope coefficient (12, r = .87)

Figure: Image Courtesy of OpenShaw

Characteristics of (Geographic) Spatial Data

3. Fractal behavior
    - What happens as scale of map changes?
    - Coast of Maine

- Implications
    - Scale is critical for the problem of study
    - Volume of geographic features tends to be underestimated
        - length of lines
        - area of polygons
    - Think of the difference of distances that an ant and elephant needed to travel from where I stand to the center of memorial circle

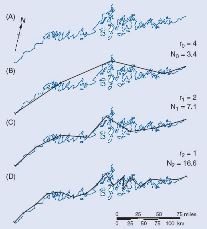


Figure 4.18 The coastline of Maine, at three levels of recursion: (A) the base curve of the coastline; (B) approximation using 100 km steps; (C) 50 km step approximation; and (D) 25 km step approximation

Please try to tell whether the following maps are micro- or macro-scale:

- https://weather.com/science/news/macro-or-micro-can-you-tell-these-images-apart-20131107

Characteristics of (Geographic) Spatial Data

Summary: three interrelated characteristics of spatial data

- Spatial context/spatial pattern/spatial structure/spatial dependence/spatial texture..
- Spatial heterogeneity/locality
- Fractal behaviors/scaling effects

Elements of Spatial Data

Elements

- Georeferenced measurements (point or area/region specific samples) Spatial arrangement: regular or irregular (gridded or scattered sampling locations)
- variables/attributes: continuous or discrete (e.g., chemical concentration, soil types, disease occurrences)
- auto- and cross-correlation endemic to spatial data (Toblers first law of Geography)

Types of spatial data

- Point pattern data
- Areal data
- Geostatisticla data
- Spatial interaction or network data

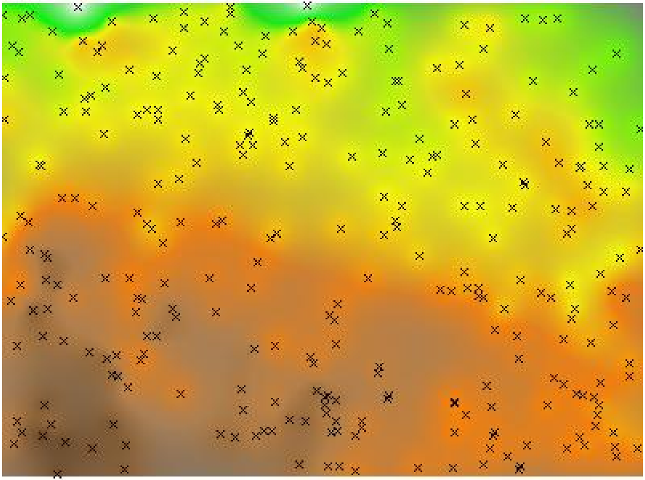
Types of Spatial Data: Geostatistical Data

Geostatistical data

- Attributes vary continuously in space, e.g., temperature, rainfall, elevation
- Measurements of nominal scale (e.g., soil types), or interval/ratio scale (e.g., depth of boreholes)
- Sampling only at fixed set of locations
- Occurs often in physical-related sciences

Types of Spatial Data: Geostatistical Data

Example: *300 randomly placed points*

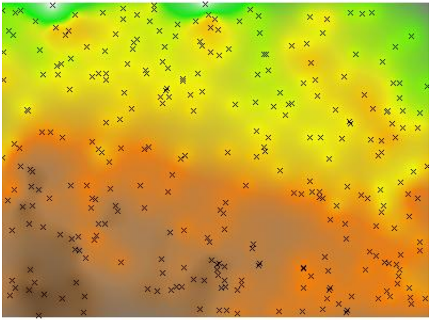


Types of Spatial Data: Geostatistical Data

Objective

- Mapping spatial variations of regional variables
- Make estimation at unsampled locations

Example: elevation surface generated from 300 points

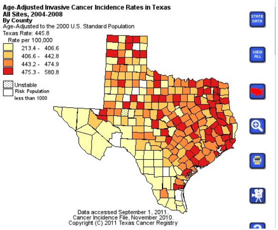


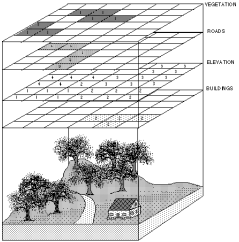
Types of Spatial Data: Areal Data

Areal (lattice) data

- attributes take values only at fixed set of areas or zones, e.g., administrative districts, pixels of satellite images
- Attributes distribute homogeneously within a region
- Lattice or uniform raster data could be taken as a special case of this type of data

Example:



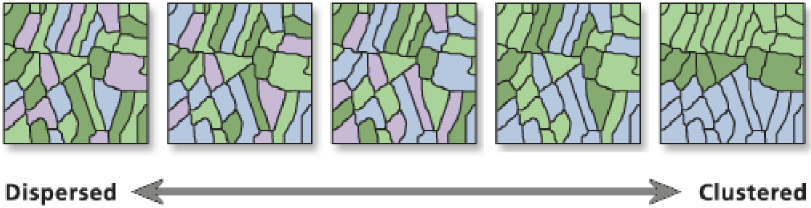


Types of Spatial Data: Areal Data

Objective

- Detect and model spatial patterns or trends in areal values
- Use covariates or relationships with adjacent areal values for inference (e.g., disease rates in light of socioeconomic variables)

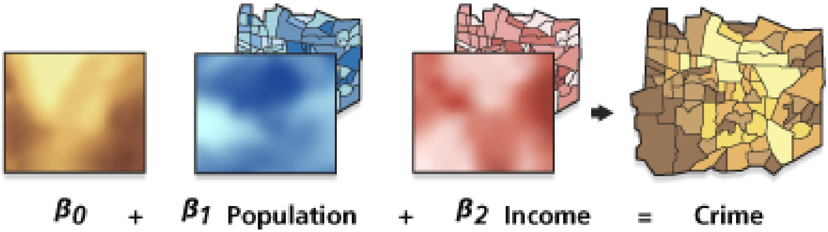
Example:



Types of Spatial Data: Areal Data

Example 2: *find the correlation among maps*

- It is analog to the cases in traditional statistics, but each variable is (multidimensional) ‘maps’ instead of single ’numbers’



Types of Spatial Data: Point Pattern Data

Point pattern data

- series of point locations with recorded events, e.g., locations of trees, epic centers, disease or crime incidents
- attribute values also possible at same locations, e.g., tree diameter, magnitude of earthquakes (marked point pattern)

Example

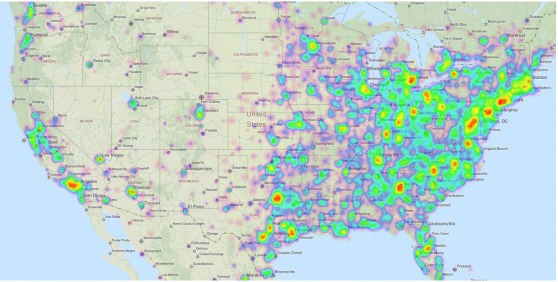
Types of Spatial Data: Point Pattern Data

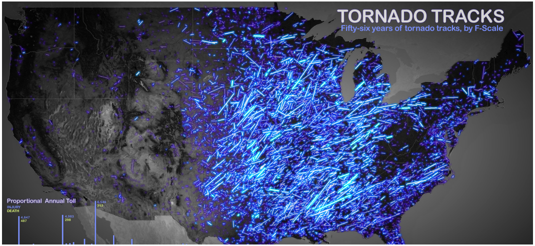
Objective

- detect clustering or regularity, as opposed to complete randomness, of event locations (in space and time)
- If abnormal clustering detected, investigate possible relations with potential factors, e.g., density of disease occurrences with socio-economic status
- Difference with geostatistical point data

Types of Spatial Data: Point Pattern Data

Example:





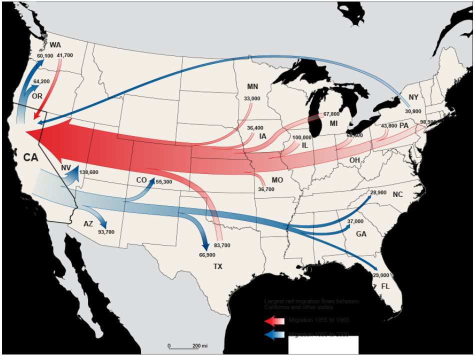
Spatial interaction or network data

- Topological space (not Euclidean space)
- Attributes relate to pairs of points or areas: flows from origins to destinations, e.g., population migrating from CA to TX
- Mostly interested in spatial patterns of aggregate interaction, rather than individuals themselves
- Not a major topic of this class

Objective

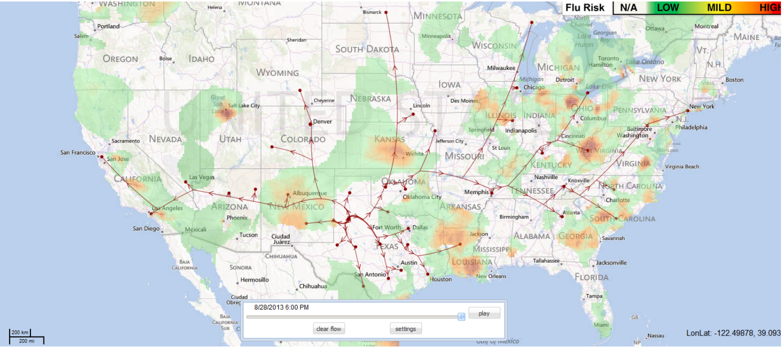
- Modeling of flow patterns
- Mostly interested in spatial patterns of aggregated interaction, rather than individual behaviors

Example



Types of Spatial Data: Spatial Interaction or Network D

Example



Types of Spatial Data: Summary

Summary

- Geostatistical data
- Spatial point pattern
- Areal (lattice) data
- Spatial interaction/network data

Representation of Spatial Data

Spatial datatase

- Before we could conduct any analysis on these data, we need to first understand
  - how these data are represented in GIS databases (e.g., shape files)
  - how to to query what are needed from the databases