GIST 4302/5302: Spatial Analysis and Modeling

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

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Map projections

• Elements in map projections
  - Datum (e.g., WGS84 ~ NAD 83, NAD 27)
  - Developable surfaces
  - Projection

• Distortions
  - shape (conformal), distance, area (equivalent), direction
  - distortions magnitude varies across a map
  - be careful of what you want to preserve

• A handy guide to a varieties of projections and their use: http://www.radicalcartography.net/index.html?projectionref, made by Bill Rankin
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
• Africa in Mercator projection
• In fact, area of Africa is about 14 times of Greenland
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)
• 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
• Comparing results of volume measures (e.g., length and area) in different map projections http://servicesbeta.esri.com/demos/compareMeasurements.html
Maps could lie, be critical 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
1. Spatial (and temporal) Context: “Everything is related to everything else, but near things are more related than distant things”

- Waldo Tobler’s 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 modifiable areal unit problem, which we will discuss more in the later of this class)
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.

<table>
<thead>
<tr>
<th></th>
<th>New Treatment</th>
<th>Traditional Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Stones</td>
<td>93% (81/87)</td>
<td>87% (234/270)</td>
</tr>
<tr>
<td>Large Stones</td>
<td>73% (192/263)</td>
<td>69% (55/80)</td>
</tr>
<tr>
<td>All</td>
<td>78% (273/350)</td>
<td>83% (289/350)</td>
</tr>
</tbody>
</table>

- Comparison of batting average of two baseball players:

<table>
<thead>
<tr>
<th></th>
<th>1996</th>
<th>1997</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derek Jeter</td>
<td>25.0% (12/48)</td>
<td>31.4% (183/582)</td>
<td>31.0% (195/630)</td>
</tr>
<tr>
<td>David Justice</td>
<td>25.3% (104/411)</td>
<td>32.1% (45/140)</td>
<td>27.0% (149/551)</td>
</tr>
</tbody>
</table>
Characteristics of (Geographic) Spatial Data

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

**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](image-url)
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
Summary: three interrelated characteristics of spatial data

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