Geographic Information Systems

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Outline

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History

- Roots in map making, which goes back hundreds of years to Henry the Navigator and earlier
- Quantitative geospatial analysis since 1970s
  - Tobler's First Law of Geography: Everything is related to everything else, but near things are more related than distant things
  - `http://en.wikipedia.org/wiki/Waldo_R._Tobler`
- Geographic information systems
  - First GIS was Canada Geographic Information System
  - Designed in the mid-60s as a computerized map measuring system
  - Many technical developments during the cold war, including GPS (Global Positioning System)
  - Modern history begins in the early 80s

Special aspects of geographic data

- Almost everything that happens, happens somewhere
- Scale or level of geographic detail is an essential problem of any GIS project
  - Local
  - Regional
  - National
- Impact on society
  - Some uses ethically problematic: Surveillance
  - Tend to emphasize homogeneity
  - Can also favor population: Impact on Arab uprisings of the early 2010s

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History of geographic information systems

- ESRI's ArcGIS
  - ESRI stands for Environmental Systems Research Institute
  - ESRI history: Company founded 1969 to work on GIS projects
  - ArcInfo launched 1981 as first commercial GIS software system
- Open source geographic information systems
  - GRASS GIS
  - QGIS
- Applications for non-experts
  - Google Maps
  - Google Earth

Services of geographic information systems

- Allow working on different scales
- Offer transformations between
  - Raster and vector data
  - Reference systems and projections
- Offer spatial operations like
  - Intersections between areas
  - Distances
  - Spatial joins, e.g., relating points to the region they are in

Geospatial indexes

- Data inherently two-dimensional
- 1-dimensional indexes, like B^+ trees not useful
- R-trees use the same block splitting ideas as B^+ trees
  - `https://en.wikipedia.org/wiki/R-tree`
- Other concepts for two-dimensional trees exist

Question 1 (multiple answers can be correct)

B^+ trees are not suitable as geospatial indexes because geospatial data

1. Are normally stored in RAM
2. Are typically much larger than other relational data
3. Are inherently two-dimensional

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Raster and vector data

- Differ in terms of
  - Storage requirements
  - Possibility to change resolution
  - Representation of n-dimensional objects
  - Ease of combining multiple layers
- Geographic Information systems can translate between them
- Information is lost when going from vector to raster format
- Important distinction in graphics as well

Raster Data

- Array of rectangular cells
- Image data typically raster data (Landsat: cells have 30m side length)
- Require projection information!
- All detail in cell is lost
- Combination of imagery with different projections (or possibly lens distortions) very challenging
- Areas represented by collection of raster points
- File size depends on resolution
- Resolution fixed

Vector Data

- Straight lines connect points (vertices)
- Often a natural representation for objects (raster representation would involve approximations)
- Areas represented by polygons
- Polyline used for 1-dimensional objects, like rivers or roads
- File size depends on density of vertices
- Resolution variable

Question 2 (multiple answers can be correct)

A satellite image is an example of

1. Raster data
2. Vector data

Question 3 (multiple answers can be correct)

A polyline that describes the perimeter of an agricultural field is an example of

1. Raster data
2. Vector data

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Georeferencing

- Any spatial coordinate requires a reference system
- Some common systems
  - Latitude / Longitude used in WGS 84 and NAD 83 (we'll get back to that)
  - Postal address: Work well for dwellings and offices but not natural features
  - IP address (Does not work when users use proxy servers)
  - Linear reference systems along a defined path on a network (may not be straight), e.g., highway miles, river miles
  - Cadaster: Map of land ownership in an area (for tax and ownership purposes), could be used for mapping but often codes are obscure

Question 4 (multiple answers can be correct)

Which of the following are coordinates in a spatial reference system in some context

1. Red River, Mile 458
2. 1340 Administration Ave, Fargo, ND 58105
3. The IP address 127.0.0.1 (this one is admittedly a trick question; if you don't know the address, please look it up)
4. 46.8772°N, 96.7898°W

Latitude and Longitude

- Latitude defined based on equator
- Longitude based on Prime Meridian which goes through the Royal Observatory in Greenwich, near London, England
- World Geodetic System 84 (WGS 84)
  - Global standard
  - Used by Global Positioning System (GPS)
- North American Datum 83 (NAD 83)
  - Used by many surveying efforts (e.g. elevation modeling, landcover maps)
- Geographic information systems can translate between them

Question 5 (multiple answers can be correct)

Where approximately is the point of zero latitude and longitude (0°N, 0°E)

1. In Fargo, we are pretty close to that
2. It was defined to be the Royal Observatory in Greenwich near London, England
3. Somewhere West of Africa
4. Where the date-line intersects with the equator

Projections

- Projections of the Earth's sphere to any 2-dimensional surface all have some problems
  - Can preserve angles: Conformal property (scales of projection in x- and y- direction always equal)
  - Can preserve area: Equal area property (areas on the map are always in the same proportion as areas measured on earth's surface)
- Mercator projection
  - Preserves points of the compass
  - Used in navigation of ships
  - Distorts areas far from the equator (gigantic Greenland)
  - Allow using 1 minute latitude (i.e., 1/60 of a degree) as distance measure: nautical mile (1852m or 1.15 miles)

Question 6 (multiple answers can be correct)

In navigation of ships, distances are typically measured in nautical miles. Is the following definition of a nautical mile plausible? One nautical mile is defined as one minute, i.e. 1/60 of a degree

1. Latitude
2. Longitude

Universal Transverse Mercator projection

- Used by Landsat (main satellite system for remote sensing)
- Most commonly used in Geographic Information Systems
- Same principle as for Mercator projection but cylinder wrapped around the poles
- 60 zones, each zone 6 degrees
- Unit of length: 1m
- Very high accuracy: Distortions < 0.05%
- Non-trivial to use: Both parallels and meridians are curved, and maps do not fit together across zone boundaries
- UTM coordinates: Zone number (we are 14N), a six-digit integer (0 to 1 million meters per zone), and a seven-digit integer (0 to 10 million meters from equator to North Pole)
- `http://en.wikipedia.org/wiki/Universal_Transverse_Mercator_coordinate_system`

Question 7 (multiple answers can be correct)

UTM (Universal Transverse Mercator) is used in Geographic Information Systems, instead of the conventional Mercator projection because

1. It allows measuring distances more accurately
2. Areas are less distorted
3. A single map suffices for representing all of Earth's surface
4. UTM coordinates are used in Google Maps and other popular applications