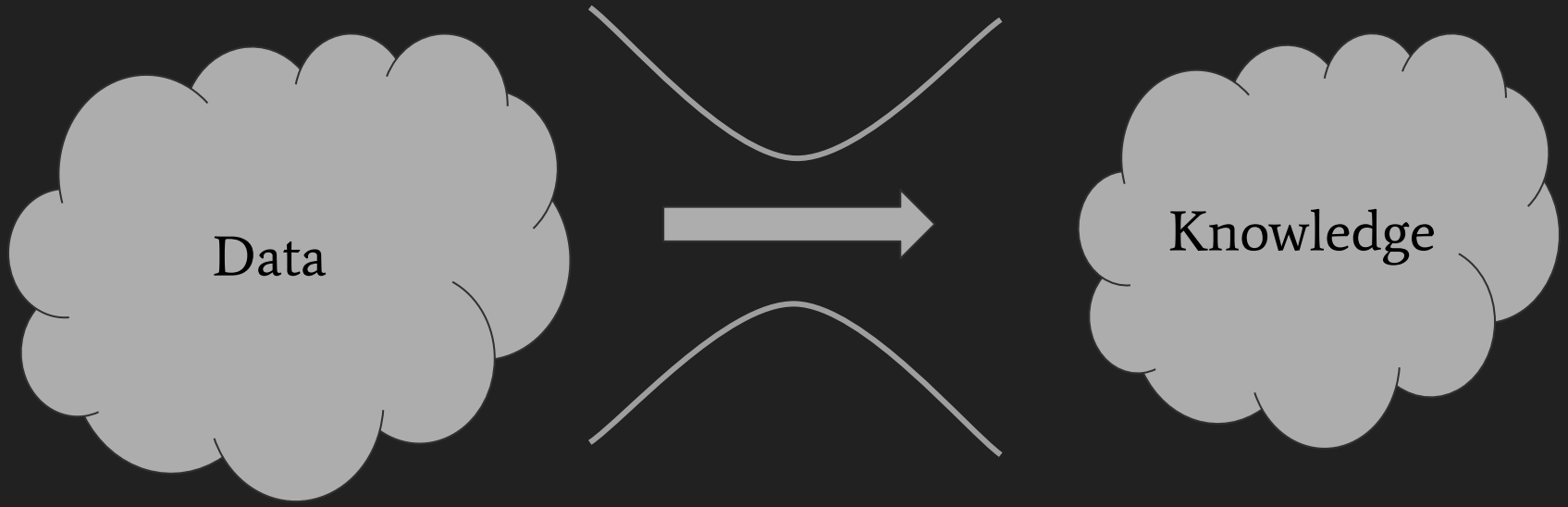
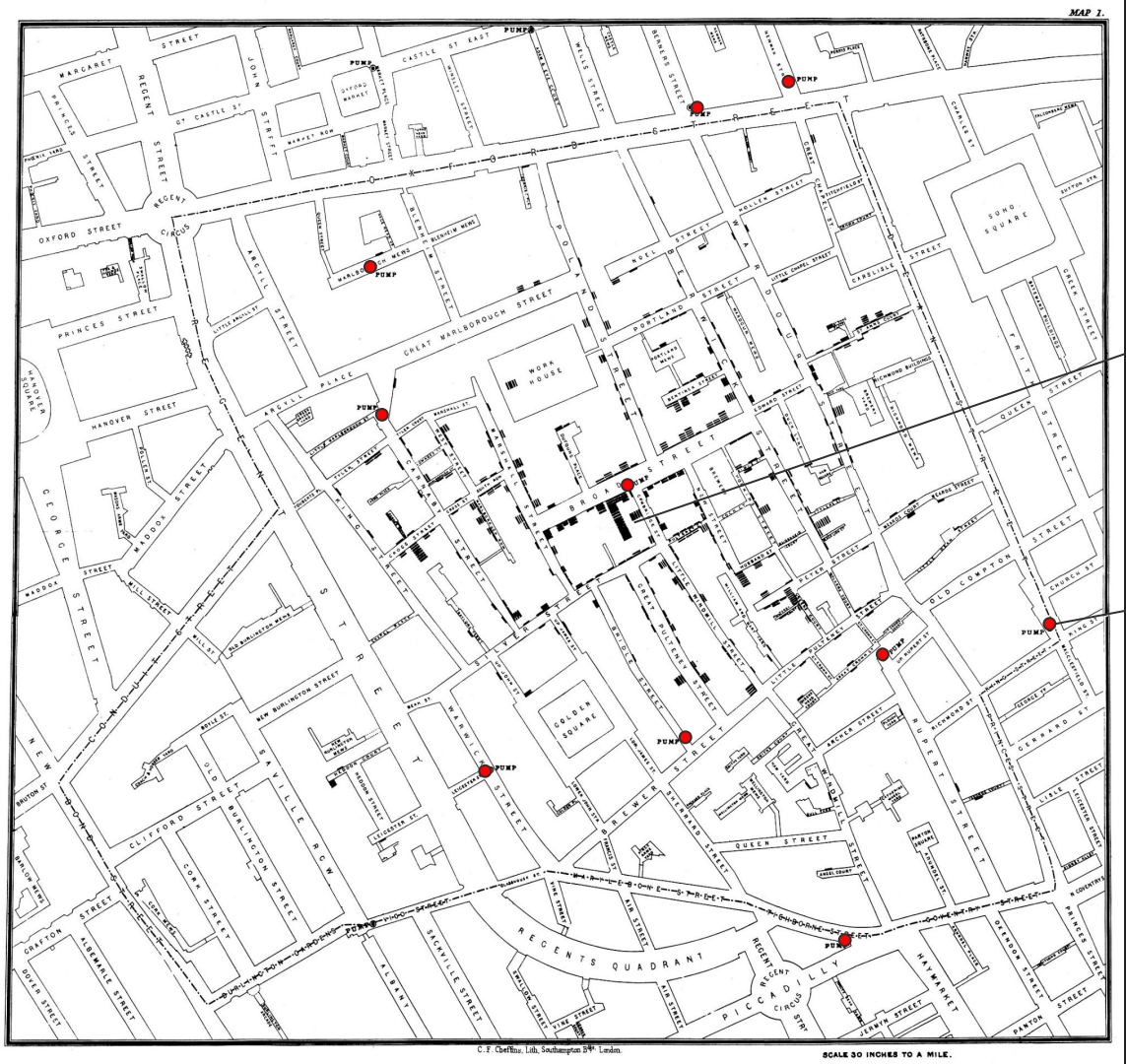
Geographic Information Systems

ESM 263 - Winter 2023

What is GIS?


Data
Knowledge



Geospatial Analysis

Cholera Cases

Pumps

Original map by John Snow showing the clusters of cholera cases in the London epidemic of 1854, drawn and lithographed by Charles Cheffins.

What is GIS?

- **Geographic**: related to the Earth's surface
- **Information**: data and metadata (context)
- **System**: functional components & connections

Burrough and McDonnell, 1998:
"a set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world"

Geographic is ...

- Location: where?
  - x = longitude
  - y = latitude
  - z = elevation
- Resolution: how precise?
- Accuracy: how reliable?
- Distance: how close?
- Area: how big?
- Distribution: how likely?
- Scale: how relevant?

"everything is related to everything else, but near things are more related than distant things." (Tobler’s Law)

Geographic data is...

- Multidimensional: x, y, z?, t?, attributes ...
- Projected: 3D Earth → 2D workspace
- Displayed: render results as maps

Location < > Information

- What's here?

  { obj ... } = f(x, y, z)

- Where's this?

  { (x, y, z) ... } = f(obj)

- Everything GIS does is an elaboration of these two functions

GIS Software

- ESRI, Inc.’s ArcGIS
  - ESRI founded 1969
  - many UCSB connections
- Open-source GIS
  - QGIS (ArcGIS work-alike)
  - more at OSGeo …
- Google Earth/Maps, Apple Maps
  - map display; not a GIS

Representing Geography

Representing Geography

- What is representation?
- Paper maps
- Digital representations
- The fundamental problem
- Discrete objects and fields

Representing the World

- Representation **standardizes** and **simplifies** …
  - complex information encoded in simple structures
  - BUT: information that doesn't fit the structure may be
    - Discarded
    - Misrepresented
- the **indirect** and **remote** …
  - space: maps, images, …
  - time: recorded history
- to extend the **direct** and **personal** …
  - space: here → horizon (~5 km)
  - time: 1 human lifetime

The Paper Map

- long and rich history
- scale (aka representative fraction)
  - ratio map distance : ground distance
  - but: what about direction? Area?
    stay tuned …
- major (historic) GIS data source
  - digitize or scan
  - register to Earth coordinates

The Digital Representation

- Digital data are binary
  - logically: 2 values (0|1, true|false, present|absent, ...)
  - physically: bistable device (on|off, +|-, N|S, ...)
- N bits → 2N distinct values
  - e.g. 8 bits → 256 values
  - integer: 0..255, -128..127
  - code: character, attribute, …
- Formats: how bit patterns are interpreted
  - JPEG: photos
  - MP3: music
  - GIS data formats: stay tuned ...

The Digital Advantage

- Economies of scale
  - One technology for all information
- Simplicity
  - Everything is a sequence of bits
- Reliability
  - Perfect copies
- Easy to detect and (usually) correct errors
- Speed
  - Closer to c than to H

The Fundamental Geographic Information Problem

Geographic information links

- Objects
  - things located in space-time
  - {point,line,area,cell} is-a {tree,road,city,...}
    - 1:1
- Attributes
  - physical, social, economic, demographic, environmental, …
  - {tree,road,city,...} has-a {DBH,route-number,population,...}
    - 1:many

For example: On 2013-03-01 at 15:00 local time, the north wall of Bren Hall had a brightness temperature of 288.7°K

The Fundamental Problem (cont’d.)

- Given potentially infinite
  - n places
  - n times
  - detail (The more closely we look at the world, the more detail it reveals)
- How do we represent
  - spatial objects
    - discrete features
    - continuous fields
  - and their attributes

Features

- Points, lines, and areas
  - single location: point
  - implicitly connected sequence of locations
    - open: line
    - closed: ring -> Polygons
  - Countable
  - persistent (through time)
  - perhaps mobile
- For example:
  - biological organisms (animals, trees, ...)
  - human-made objects (vehicles, houses, fire hydrants, ...)

Fields

- Phenomena that vary continuously in space
  - value is a function of location
  - property can be any attribute type (including direction)
- Canonical example: elevation
  - single value at every point on Earth’s surface
  - how we speak about fields:
    “high”, “low”, “steep”, “peak”, …
- Other examples
  - soil moisture
  - atmospheric pressure
  - albedo

Feature or Field?

- Population density
  - depends on scale
- Land ownership
  - continuous, but defined in terms of features
- Lake
  - how defined?
- Weather
  - systems, fronts, ...