Geographic Information Systems: Introduction

Agenda

- **Adminstrivia**
  - https://purl.org/ucsb-bren/ESM263
- What is GIS?
- Representing geography

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- Adminstrivia
- **What is GIS?**
- Representing geography

What is GIS?

- **G**eographic: related to the Earth's surface
- **I**nformation: data and metadata (context)
- **S**ystem: 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**?

Location ↔ Information

- What's here?

$$i = f(x, y, z)$$

- Where's this?

$$(x, y, z) = f(i)$$

- Everything GIS does is an elaboration of these two functions

Geographic is special...

- **Multidimensional**: *x, y, z, t*, parameters...
- **Voluminous**: godzillabytes*/ item
- **Projected**: 3d Earth → 2d workspace
- **Conflation**: merge multiple data sources
- **Updates**: spatial connectivity makes difficult
- **Display**: render results as maps

* a real pain to deal with

GIS software

- ESRI, Inc.'s ArcGIS
  - ESRI founded 1969
  - many UCSB connections
- Open-source GIS
  - QGIS
  - GRASS
  - more at OSGeo ...
- Google Earth
  - (map display; not a GIS)

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- Adminstrivia
- What is GIS?
- **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

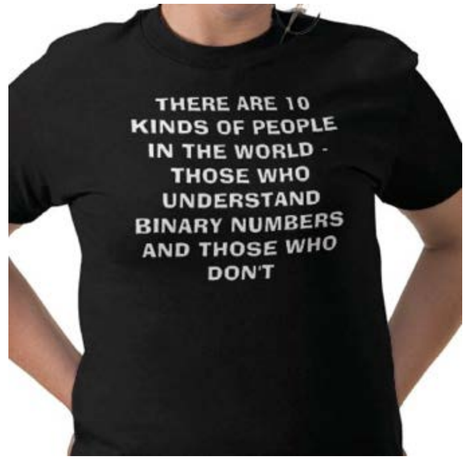
The Paper Map

- long and rich history
- **scale** or **representative fraction**
  - ratio map distance : ground distance
- major (historic) GIS data source
  - digitize or scan
  - register to Earth coordinates
- BUT: digital representations much more
  - powerful
  - flexible

  than paper equivalents

The Digital Representation

- Digital data are binary
  - logically: 2 values (0|1, true|false, present|absent, ...)
  - physically: bistable device (on|off, +|-, N|S, ...)
    - **bit**



- N bits → 2^N 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 **3 pm local time**, the **north wall** of **Bren Hall** had a **brightness temperature** of **288.7°K**

The Fundamental Problem (cont'd.)

- Given potentially infinite
  - # places
  - # times
  - detail
    - The more closely we look at the world, the more detail it reveals

- How do we represent
  - **objects**
    - discrete **features**
    - continuous **fields**
  - **attributes**

Features

- Points, lines, and areas
  - single location
    - **point**
  - implicitly connected sequence of locations
    - open: **line**
    - closed: **polygon**
  - 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, ...

Attributes: *Scales of Measurement*

- Nominal
  - distinction (“a” is/is-not “b”)
    - e.g. land cover class
- Ordinal
  - significance (“a” is Xer than “b”)
    - sortable
    - e.g. good → better → best}
- Interval
  - relative magnitude (“a” is N units Xer than “b”)
    - interpolable
    - e.g. degrees Celsius

Scales of Measurement (cont'd)

- Ratio
  - absolute magnitude ("a" is N times Xer than "b")
    - scalable
      - true zero: absence of attribute
    - e.g. degrees Kelvin

- Cyclic
  - direction
    - more common in geography than in other disciplines
    - "wrap-around" discontinuity at 2π (360°)
      - difficult to interpolate
    - e.g. terrain exposure ("south-facing slope")