Introduction to Geographic Information Systems

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Necessary Stuff

The Ronald Greeley Center for Planetary Studies

- Social distancing, if possible
- Mask optional
- No food
- No open drinks; covered ok

When are we actually open?
- By appointment is best (10:30 – 5:00)
The GIS Lab

Who I Am: David Nelson: M.S. Geology & M.A. Geography (GIS)
- Data Manager / Geospatial Data Analyst / GIS consultant
- Planetary geologist, work with mission data
- Participated on active planetary missions (LROC)

PSF-560 Computer Lab: 6 Dell Workstations (Windows 10)
- ArcGIS Pro 3.2.x
- A working knowledge of Windows REQUIRED for ArcGIS!

Also:
- Jmars 5, QGIS, Acrobat, Photoshop, Illustrator, MS Office
Overview of GIS Seminars

Seminar 1 – March 26, 28, 30
1) The Lecture: Concepts in GIS
   ❖ GIS data types, projections
2) Exercise 1: The ArcGIS Pro Interface
   ❖ Navigate & explore ArcGIS Pro

Seminar 2 – April 2, 4, 5
3) Exercise 2: Working with Rasters
4) Exercise 3: Working with Vector Data
GIS Lecture Overview

Concepts in GIS —

- What is GIS?
- Spatial data types: raster & vector
- What can GIS do? Solve spatial problems!
- Map Projections: from 3D to 2D
- Planetary data & where to get it
  - (PDS, USGS, Data warehouses)
What Is GIS?

GIS stands for: Geographic Information Systems

One explanation:

A database system that uses spatial and aspatial data in order to answer questions about where things are geographically and how they are spatially related.
Spatial data provide graphically-represented information about the physical (geographic) extent of surface features.

- **Geometry**: Point, Line (Polyline), or Polygon; Pixels
- **Spatial Characteristics**: Area, Perimeter, Length
- **Topology (not topography!)**: Spatial relationship between two or more spatial objects
Example of Spatial Data

Surface features:
• Base image
• Geologic units
• Linear & structure

Q: Is annotation spatial data?

And Aspatial Data?

Aspatial (non-spatial) data are the attributes or characteristics of the mapped geographic features.

A table of values

- measurable: area, perimeter, topography
- statistical: surface composition, demographics
- ancillary: name, date, site number
Aspatial data: Tables

- Tables contain information (text, numbers, dates)
- Several data sources (notes, survey, photo meas.)

What about the “S” in GIS?

Two key concepts: physical and analytical

1) A physical system:
   - data, hardware, software, procedures, and people
   - the compiling of spatial data
   - database management
   - “button-ology” – the mechanics/process
What about the “S” in GIS?

Two key concepts: physical and analytical

2) An analytical method of spatial data analysis:
   - Quantification of spatial extent
   - Identification of relationships of geographic objects
   - Problem solving
GIS topics

- GIS is used to solve spatial problems:
  - Objects - What is it?
  - Locations – Where is it?
  - Associations – How are objects related?
  - Patterns – How are features arranged?
  - Temporal trends – What has changed?
GIS Data

https://paititi.info/research-technology/geographic-information-systems/
1) Raster – Images consisting of pixels
   - Shows “real world” surface features
     - reflection & emission (wavelength)
     - brightness, color, contrast

2) Vector – Points, lines, polygons
   - Represents features symbolically
     - outlines, line weight/symbol
     - unique icon
     - colors/patterns
Both data models are:

- Spatial – geographic shape and extent
- Georeferenced –
  - tied to a particular location in space
  - referenced by a coordinate system
    (location on surface)
The Raster (image) Model

Raster data characteristics:

- Matrix (array) of square cells or ‘pixels’ (picture element)

- Pixels are spatially referenced by coordinates \((x, y)\) – internal/external system

- Spatial dimensions of pixels determine raster resolution
The Raster (image) Model

- Resolution:
  More pixels = more info = larger files

Lowell Observatory, 1930
US Naval Observatory, 1978
Hubble, 2002
New Horizons, 2015

At what point do we have enough data to begin mapping?

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The Vector (outline) Model

Coordinate pairs (vertex/vertices, nodes, points)
  - direction and length between are calculated between points
The Vector (outline) Model

Purpose: To simplify images into groups of features

- classify common features
- symbolize and annotate

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The Vector (outline) Model

Symbolic feature representation

- Three basic object types:
  - points (0 D)
  - lines/polylines (1 D)
  - polygons (2 D)

- Consist of:
  - Point coordinate pair (x,y)
  - Vector: direction & length
**Definition:** “Data about data”

- Metadata best if in a **standardized** format (content styles), most commonly: **FGDC** – Federal Geographic Data Committee

- Data supplied without metadata is often considered **incomplete** (untrustworthy?)
  - Origin?
  - Publisher?
  - Date?
**Metadata**

**metadata**

**Metadata** are data about data. Dependable digital geographic data will include detailed information including:

- **identification information**: general description of the data
- **data quality information**: in terms of data quality standards
- **spatial data organization information**: how spatial information in the data is represented
- **spatial reference information**: coordinate and projection information
- **entity and attribute information**: map data and associated attributes
- **distribution information**: data creator, distributor, and use policy
- **metadata reference information**: metadata creator
- **citation information**: how to cite information when used
- **temporal information**: when data was collected, updated
- **contact information**: how to contact data creator

Source: Longley et al., *Geographic Information Systems and Science*, 2001

**Metadata** standards in the U.S. have been set by the Federal Geographic Data Committee (FGDC, www.fgdc.gov). Geographic data providers often follow such guidelines. For example, see the extensive geographic data available at www.geographynetwork.com, all of which are provided with metadata that meet FGDC standards.
Components of the Model
- 3D: Datum (shape)
- 2D: Projection (cartesian plane)
- Coordinate system: Surface reference
3D Datum (shape):

- No planet is a perfect sphere
  - Flattened at the poles, bulges near equator
- Approximated by the geoid
  - Mathematical model of the planet’s shape
  - Recent geoids are based on satellite and gravimetric surveys
- Simplified as a spheroid
  - Major & minor axes
Spheroids and Datums

Idealized models

Actual shape

Fitted compromise

--M. Price "Mastering GIS", 2014
Coordinate System:

- An agreed upon graphic reference used to indicate surface locations
  - On shape or surface: latitude and longitude
  - In space: right ascension and declination

- **Origin point** (reference): 0,0
  - All surface locations referenced from this position

- **Map units** (degrees, meters, ...):
  - Enables measuring distances and area
2D Projection (plane):
- To represent shape on paper map, computer screen
- **Projection**: mathematically-defined model
  - Converts degrees of latitude & longitude (3D) to planar x,y coordinates (2D)
- Major projection types:
  - Cylindrical
  - Conic
  - Orthographic
  - Stereographic

http://www.geography.hunter.cuny.edu/~jochen/gtech361/lectures/lecture04/concepts/Map%20coordinate%20systems/Cylindrical%20projections.htm
Map Projections

- Conic projection
- Cylindrical projection
- Plane projection
- Interrupted projection

--visualdictionaryonline.com
Map Projections

Where most problems occur in GIS!

Is Greenland really that big?

Sanity check!

Red circles represent equal areas
Map Projections

Compromises in shape vs. area

Red circles represent the same area, but distortion is evident.
Map Projections

The trade offs: direction, shape, area
All maps have a scale:

- Represented as a fraction (or ratio) 
  \[ \frac{1}{x} \]
- Scale Bar
- ArcGIS: listed in menu bar

- Small scale: less detail (1:5,000,000)
- Large scale: more detail (1:500)
Scale in GIS - Considerations

- Map at a scale **appropriate** to your topic of study
- Don’t always map at large scale (more detail than needed)

Q: Which outline is “better”? 

Q: Does a zoom-able map have a scale? Contentious!

--M. Price “Mastering GIS”, 2014
Planetary Data

Geologic Map of the Nearside of the Moon

1:5M
Orthographic Proj.

Wilhelms & McCauley

USGS, 1971
Planetary Data

GIS and Data Acquisition
Platform independent
Planetary Data

Global and regional image and GIS datasets; historic geologic maps


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Archive of planetary mission data

PDS-hosted sites:
- Main site: http://pds.nasa.gov
- Imaging Node: https://pds-imaging.jpl.nasa.gov
  (Cartography and Imaging Sciences Discipline Node)
- Geosciences Node: https://pds-geosciences.wustl.edu
Planetary Data

- Comprehensive sites in continuous development

- NASA Space Science Data Coordinated Archive
  https://nssdc.gsfc.nasa.gov/

  Mission descriptions, data, tutorials, …

https://ode.rsl.wustl.edu/mercury/pagehelp/Content/Introduction/Introduction.htm
Planetary Data

Each mission has its own site; each instrument has its own site

- As long as the mission is in flight
- And funds are available to host & maintain the sites:

Moon: LRO - LROC
http://lroc.sese.asu.edu/archive

Mercury: MESSENGER - MDIS
https://messenger.jhuapl.edu/Explore/Images.html

Mars: MRO
https://mars.nasa.gov/mro/
Map and Geospatial Hub
Hayden Library - https://lib.asu.edu/geo

The ASU Library Map and Geospatial Hub advances the use of geographically-referenced information by expanding access to and support for geospatial technologies and cartographic resources across ASU and beyond.

Need to request resources or an appointment?

Make a service request