GIS for Research I

Introduction to GIS Concepts, Software, and Data

James Whitacre
GIS Specialist
Scholarly Commons
Instructor: James Whitacre

• GIS Specialist
  Scholarly Commons, Main Library at the University of Illinois at Urbana-Champaign

Previously:
• GIS Manager
  Carnegie Museum of Natural History

• Master of Science in Geography, concentration in GIS and Cartography
  Indiana University of Pennsylvania

• Bachelor of Arts in Zoology
  Ohio Wesleyan University
GIS at Scholarly Commons

• Provide GIS research consultations and basic services

• Provide GIS workshops and training

• Manage the University Library’s geospatial data and GIS software resources

• Act as a central resource for the University’s GIS community and promote the use of GIS in research and teaching
GIS for Research Core Workshops

• GIS for Research I: Introduction to GIS Concepts, Software, and Data

• GIS for Research II: GIS Research, Data Management, and Visualization

• GIS for Research III: Geoprocessing, Analysis, and Web GIS

Slides available at http://guides.library.illinois.edu/gis
Special Topics GIS Workshops

• ArcGIS Online and Story Maps
• ModelBuilder and Python in ArcGIS
• Field data collection techniques and Collector for ArcGIS
• Geocoding and Georeferencing
• Spatial Analysis Techniques: Interpolation, Clusters, Statistics, and more
• Lidar and 3D mapping techniques
Learning Objectives

• Begin to learn to think spatially about data and research

• Overview of different types of GIS software tools and data

• Introduction to ArcGIS Desktop

• Overview of foundational geospatial concepts and analyses

• Familiarity with GIS resources available for further investigation
What is GIS?

Geographic Information System AND Science
Geographic

- Relating to Geography

- *Geography* is the study of the lands, the features, the inhabitants, and the phenomena of Earth

- Human vs. Physical Geography

Thinking Spatially

- **Place** – meaningful or important location; can be conceptual or real
- **Space** – distance between places
- **Spatial** – Related to or existing within space
- **Geographic** – Of or relating to earth space
- **Geospatial** – Catch all term that refers to everything above; usually used in the context of analysis or technology
- ‘Real’ vs. ‘Socio-Cultural’ constructs of geography
Geographic Information

• Information about places and features on the Earth's surface

• Knowledge about *where* something is

• Knowledge about *what* is at a given location

Geographic Information System

- Computer hardware and software
- Spatial information and data(bases)
- Spatial and statistical analysis
- Geography and maps drive the underlying concepts and theories
- Powerful tool that must be handled with care to not misuse it

# Desktop GIS Software

## Traditional GIS Software

<table>
<thead>
<tr>
<th>Proprietary (usually not free)</th>
<th>Free (usually open source)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• ArcGIS Desktop</td>
<td>• QGIS</td>
</tr>
<tr>
<td>• TerrSet/IDRISI</td>
<td>• GRASS</td>
</tr>
<tr>
<td>• ERDAS IMAGINE</td>
<td>• PostGIS</td>
</tr>
<tr>
<td>• MapInfo</td>
<td>• MultiSpec **</td>
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<tr>
<td>• MicroStation</td>
<td>• SAGA</td>
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<tr>
<td>• AutoCAD</td>
<td>• uDig</td>
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<tr>
<td>• Google Earth Pro*</td>
<td>• GeoDa</td>
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<tr>
<td></td>
<td>• Google Earth**</td>
</tr>
</tbody>
</table>

*Recently became free!*

**Not open source**
# Web GIS Software

**The Future!**

## GIS and Map Servers
- ArcGIS Server
- GeoServer
- MapServer
- OpenGeo Suite*
- Others

## Cloud GIS and Map Services
- ArcGIS Online
- Mapbox
- CARTO
- GIS Cloud
- GeoCloud2
- Others

## Web Mapping APIs
- ArcGIS API for JavaScript
- Google Maps API
- Leaflet
- OpenLayers
- Many others!

*Includes GeoServer
Geographic Information Science

- Research that studies the theory and concepts that underpin GIS

- Establishes a theoretical basis for the technology and use of GIS

- Commonly an interdisciplinary approach to research and investigation

- Two forms:
  - Research about GIS that leads to improvements in the technology
  - Research that uses GIS as a technology tool for the advancement of science

GIS in Research
What is Spatial Thinking in Research?

- Applying geographic principles of place, time, and distance
- Ability to conceptualize research questions and methods in light of place, distance, and time
- Ability to integrate different forms of spatial data and explore spatial patterns
Why Think Spatially in Research?

- Contextualizes relationships, patterns, and connections in space and time
- Results in more holistic and realistic picture of the data
- Enables better visualization, communication, and implementation of research
- Most data is spatial → it can be tied or linked to a specific location on the earth
For Research…

Aren’t GPS Coordinates Good Enough?
For Research...

Aren’t Geographic Coordinates Good Enough?
Advantages of Using GIS in Research

• Comprehensive approach to research problem solving
  – Quantitative
  – Qualitative

• Analyze large amounts of data in a spatial context and at different scales

• Data management, analysis, and visualization tool all in one
Framing Research for GIS

- Key in determining how GIS can or will be used in your research

- Requires concise research questions for what you want to accomplish with GIS

- Analysis will influence research question(s)

- Results or final product will influence research question(s)
Who uses GIS in Research?

Intradisciplinary  Multidisciplinary  Crossdisciplinary  Interdisciplinary  Transdisciplinary

Understanding Maps
What is a map?

• Symbolic and visual representation of a place

• Contains only selected characteristics or features

• Highlights spatial relationships of different features

• Usually drawn on a flat surface at a specific scale
Scale

• Maps cannot show features at their actual size
• Scale represents the reduction between the map and the real world
Small vs. Large Scale

1:100,000 scale (small scale)
- 20 times no. of lines
- 3 times total length of lines
- 1:100,000 scale – 557 lines,
- Total length 1890 km

1:24,000 scale (large scale)
- 1:24,000 scale – 11,338 lines,
- Total length 5559 km
Print vs. Digital Maps

Print:
- Printed and viewed on paper or other physical media
- Static view

Digital:
- Viewed on a computer or projected screen
- Dynamic and Static views
Maps in GIS

Map:

• Location
• Quantities
  • Densities
• What is nearby
• What overlaps
• Change
• Map so much more!
Geospatial Data

• Where and what something is...

• Can be shown on a map

• If data has location info (e.g. latitude and longitude, addresses, place names, etc.) it is geospatial data

• Examples include counties, streams, nesting locations, hillshades
Exercise 1

Explore ArcGIS for Desktop
Acquiring Geospatial Data
But...

How do I get and use GIS data for my research?
Data Collection

- GPS data collection technologies
- Surveying techniques
Digitizing and Drawing

• Using GIS software to create vector data features

• Trace features from aerial images or georeferenced scanned maps
Geocoding

Process of transforming a description of a location—such as a pair of coordinates, an address, or a name of a place—to a location on the earth's surface
Download/Access from the Internet

There are thousands of geospatial data websites waiting for you to download their data!
Searching for Data on the Web

• Be specific with geographic location, theme, time frame, etc.

• Add ‘GIS data’ and/or ‘shapefile’ to the end of your search string

• With results, look for reputable sites like known organizations or government entities
Browse Geospatial Data Repositories

• US, State, County, and Local Government or Departmental websites

• US State Clearinghouse websites

• Non-profit, Academic, and other organizations who work with geospatial data
Metadata

• Data about data...

• Describes quality, condition, origin, and many other characteristics

• Includes information on timeframe, vintage, availability, distribution, and licensing

• Might include a data dictionary – an explanation of attributes and codes
Geospatial Metadata

• Includes information such as geographic location or extent, coordinate system, and scale or resolution

• Two primary standards in the US
  – FGDC Content Standard for Digital Geospatial Metadata (CSDGM)
  – International Organization for Standardization (ISO) 19115 (and other related in the 19100 group)
Exercise 2

Download and Organize Geospatial Data

Acquire Geospatial Data

Analyze Geospatial Data

Present Geospatial Data
Download Data

http://www.naturalearthdata.com/
Geospatial Data
Layers

- Geospatial data is arranged by layers on a map in GIS

- Collection of similar or thematic geographic features

- All features must be the same type of data (point, line, polygon, raster) and share the same set of attribute types (or fields)

In GIS software, layers:

- Define visualization or symbology and other essential properties

- Do not store data, but reference (i.e. point to) data sources
Geospatial Data Models

Two Basic Types:

• Vector

• Raster
Vector Data

- A coordinate-based data model that represents geographic features as points, lines, and polygons
- Point features represented as a single coordinate pair
- Line and polygon features represented as ordered lists of vertices
- Attributes are associated with each vector feature
Where something is...

A representation of a real-world object on a map translated by a coordinate system

Four main components
- **Shape** or **geometry**
  - Points → cities
  - Lines → rivers
  - Polygons (areas) → countries
- **Location**: geographic coordinates
- **Symbol**: shape, color, pattern, outline
- **Attributes**: describes the feature
Attribute Information

• What something is...

• Describes features

• Stored as a data table connected to the features

• Examples include city names, stream length, or country population
Shapefile Feature Classes

- Simple vector format with features connected to dBASE format table

- Stores location, shape, and attributes of point, line, or polygon geographic features

- Requires at least three and up to 16 separate files stored in same workspace (i.e. folder)

Geodatabase Feature Classes

• Similar to a Shapefile, but with more functionality

• Four common types: points, lines, polygons, and annotations

• Optimized for analysis with better storage efficiency and capacity

• Stored in a Geodatabase
Geodatabases

- Stores feature classes and various other GIS and non-GIS data types, including standalone tables, raster datasets, and many others.

- Intended to replace Shapefiles as the primary native format for ArcGIS.

- Three formats/types in ArcGIS:
  - **File Geodatabase** – stored in a files system folder
  - Personal Geodatabase – stored as Microsoft Access data files
  - Enterprise Geodatabase – stored in relational DBMS such as Microsoft SQL Server, Oracle, or PostgreSQL

- Generally readable in other GIS software and other formats/types exist in open-source sphere.
**Raster Data**

- A spatial data model that defines space as an array of equally sized cells arranged in rows and columns

- Can be composed of single or multiple bands

- Each cell contains an attribute value and location coordinates
Raster Data Examples

• Digital Elevation Models
• Land Cover
• Aerial Imagery
• Scanned Maps
Raster Data Formats

• TIFF
• JPEG, JPEG2000
• MrSID
• ArcGIS GRID
• Geodatabase Raster
• Many others!
Resolution

• In GIS and Remote Sensing: The real-world dimensions represented by each cell or pixel in a raster
• Example: 10 meters, 30 meters, 90 meters, etc.
Resolution
Scale vs. Resolution

Scale → Vector

Resolution → Raster

• In general:

Map Scale Denominator = Raster resolution (in meters) * 2 * 1000

<table>
<thead>
<tr>
<th>Map scale</th>
<th>Detectable size (in meters)</th>
<th>Raster resolution (in meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:1,000</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>1:5,000</td>
<td>5</td>
<td>2.5</td>
</tr>
<tr>
<td>1:10,000</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>1:50,000</td>
<td>50</td>
<td>25</td>
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<td>1:100,000</td>
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<td>1:250,000</td>
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<tr>
<td>1:1,000,000</td>
<td>1,000</td>
<td>500</td>
</tr>
</tbody>
</table>

• It is not good practice to perform analyses on data intended for different scales/resolution.

Should I Use Vector or Raster Data?

Is your data **Discrete** or **Continuous**?

- **Discrete**
  - Individually distinguishable
  - Phenomenon does not exist between observations
    ex. lakes and roads

- **Continuous**
  - Gradual variation across a range of values
  - Values exists between observations, but maybe not always measurable
    ex. temperature and elevation

- **Both Vector and Raster data can model discrete and continuous data, but...**
  - Vector data → better for discrete data
  - Raster data → better for continuous data

- **Decision also depends on the scale or resolution of data, analysis workflow, and tools available**
**Data Measurement Types**

**Discrete**
- Classified
  - Nominal: Land Use
- Ranked
  - Ordinal: Road type

**Continuous**
- Relative
  - Interval: Contours
- Absolute
  - Ratio: Rain fall

**Qualitative**
- Text

**Quantitative**
- Integer/Date
- Float/Double


Is Contour Data Discrete or Continuous?

Elevation Contours

• What is being visualized?

• Are Contours vector or raster data?
Web Layer Services

• GIS data served over the internet using a GIS server

• Viewed in a web browser or desktop GIS software

• Typically published from traditional GIS formats to a GIS server or web mapping platform

• Two basic types of web map services
  – Feature Layer Services
  – Tile Map Services
Feature Layer Services

Feature Layers → Vector

- Published from vector datasets
- Individual feature attribute information is accessible
- Can be used for GIS analysis on the web
Tile Map Layers

**Tile Layers → Raster**

(or Raster-like)

- Pre-drawn map images tiled to appear seamless
- Good for fast map visualization over the web
- Good as basemaps to give geographic context
- Individual feature attribute information NOT ALWAYS accessible
Exercise 3

Working with Geospatial Data
Coordinate Systems and Map Projections
Coordinate Systems in GIS

Two types in GIS:

- Geographic Coordinate Systems (GCS)
- Projected Coordinate Systems (PCS)
Geographic Coordinate Systems

- Based on a \textit{spheroidal} model of the earth
- Reference lines are parallels (latitude) and meridians (longitude)
- Uses geographic coordinates and angular measurements \((x,y)\) where \(x\) is lon., \(y\) is lat) to define unique positions on the earth
- Defined primarily by a geographic datum
Projected Coordinate Systems

- Portrays curved/spherical surface of the earth to planar or flat surface
  - Systematic mathematical transformation of the earth's lines of longitude and latitude onto a plane
  - Uses length-based units (m and ft)

- Introduces distortion of the map data, but designed to minimize:
  - Distance → Equidistant
  - Area → Equal area
  - Shape → Conformal
  - Direction → Azimuthal
Projected Coordinate Systems

Three primary types:

• Planar – surface is tangent to the globe

• Conical – surface formed into a cone

• Cylindrical – surface is formed into a cylinder
Why are Coordinate Systems Important?
Exercise 4
Discovering Coordinate Systems and Projections
GIS Resources
GIS for Research Workshops

• **GIS for Research I: Introduction to GIS Concepts, Software, and Data**
  – Thurs. Sept. 21 1-3pm & Fri. Nov. 3, 1-3pm, rm. 314

• **GIS for Research II: GIS Research, Data Management, and Visualization**
  – Thurs. Sept. 28 1-3pm & Weds. Nov. 8, 1-3pm, rm. 314

• **GIS for Research III: Geoprocessing, Analysis, and Web GIS**
  – Thurs. Oct. 5 1-3pm & Fri. Nov. 11, 1-3pm, rm. 314
Special Topics GIS Workshops

• **Sharing Research with Story Maps**
  – Tues., October 17, 3-4pm, room 314
  – Thurs., November 2, 2-3pm, room 314

• **Geocoding**
  – Thursday, October 19, 2 – 3 pm, room 314
Special Topics GIS Workshops

• Introduction to Python for ArcGIS
  – Friday, December 1, 1 – 4pm, room 314

• Advanced Python for ArcGIS
  – Friday, December 8, 1 – 4pm, room 314
Introductory Classes

• Geography and GIS Department
  – GEOG 371: Spatial Analysis
  – GEOG 379: Introduction to GIS
  – GEOG 380: GIS II: Spatial Problem Solving
  – Many more...

• Urban Planning
  – UP 418: GIS for Planners
  – UP 519: Advanced Applications of GIS

• Natural Resources and Environmental Sciences
  – NRES 454: GIS in Natural Resource Management
  – NRES 455: Advanced GIS for Natural Resource Planning

• iSchool
  – LIS490GI: Geographic Information Systems
Library Resources

• **Scholarly Commons GIS Services:**
  – GIS data discovery and research services
  – GIS consultations by appointment
  – [http://www.library.illinois.edu/sc/datagis](http://www.library.illinois.edu/sc/datagis)
  – [http://guides.library.illinois.edu/gis](http://guides.library.illinois.edu/gis)

• **Map Library:**
  – Geospatial datasets, GIS reference books and journals, aerial photos, paper maps, etc.
  – [www.library.illinois.edu/max](http://www.library.illinois.edu/max)
Questions?
Thank You!

James Whitacre, GIS Specialist
Scholarly Commons, Room 306 University Library
jvwhit@illinois.edu

Please feel free to contact me for further assistance.