Geographic Information Systems 101:

Understanding GIS

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Scholarly Commons
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- **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 services and consultation

• 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
Learning Objectives

• Learn to think spatially about data and research

• Understand how to frame and ascertain research questions and methods using GIS

• Overview of different types of GIS software tools and data

• Overview of foundational geospatial concepts and analyses

• Familiarity with GIS resources available for further investigation
GIS Workshops

Core Workshops

• Geographic Information Systems 101: Understanding GIS

• GIS for Research I: Tools, Concepts, and Geodata Management

• Discovering GIS Data

• GIS for Research II: Geoprocessing, Analysis, and Visualization
GIS Workshops

Special Topics

• 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
What is GIS?

Geographic Information System or Science
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

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

Sources:
http://www.ncgia.ucsb.edu/giscc/units/u002/u002.html
Think: Spatially
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
In Research...

Aren’t GPS Coordinates Good Enough?
GIS in Research
Who uses GIS in Research?

Geography, Ecology, Environmental Sciences, Forest Science, Geology, Engineering, History, Archeology, Anthropology, Literature, Political Science, Business, Economics, Biology, Public Health, Medicine, Education, Public Administration, Agriculture, Urban Planning, Atmospheric Sciences, Library and Information Science, Journalism, Veterinary Medicine, Social Work, Criminology...
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)
GIS Maps, Software, and Data
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
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!
## 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 for 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>
</tr>
<tr>
<td>• MicroStation</td>
<td>• SAGA</td>
</tr>
<tr>
<td>• AutoCAD</td>
<td>• uDig</td>
</tr>
<tr>
<td>• Google Earth Pro*</td>
<td>• GeoDa</td>
</tr>
<tr>
<td></td>
<td>• Google Earth**</td>
</tr>
</tbody>
</table>

*Recently became free!  
**Not open source
# Web GIS Software

## The Future!

<table>
<thead>
<tr>
<th>GIS and Map Servers</th>
<th>Cloud GIS and Map Services</th>
<th>Web Mapping APIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>• ArcGIS for Server</td>
<td>• ArcGIS Online</td>
<td>• ArcGIS API for JavaScript</td>
</tr>
<tr>
<td>• GeoServer</td>
<td>• Mapbox</td>
<td>• Google Maps API</td>
</tr>
<tr>
<td>• MapServer</td>
<td>• CartoDB</td>
<td>• Leaflet</td>
</tr>
<tr>
<td>• OpenGeo Suite*</td>
<td>• GIS Cloud</td>
<td>• OpenLayers</td>
</tr>
<tr>
<td>• Others</td>
<td>• GeoCloud2</td>
<td>• Many others!</td>
</tr>
</tbody>
</table>

*Includes GeoServer
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
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
Features

• 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 Class

• 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!
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 exist 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
- Relative: Interval Contours

Continuous
- Absolute: Ratio Rainfall

Qualitative
- Text

Quantitative
- Integer/Date
- Float/Double

Helpful resources:

Is Contour Data Discrete or Continuous?

Elevation Contours

- What is being visualized?
- Are Contours vector or raster data?
Web Map/Layer Services

Two basic types of web map services

• Allows GIS data to be served to the internet and viewed in a web browser
• Typically published from traditional GIS formats to the web

Feature Layers → Vector

• Published from vector datasets
• Individual feature attribute information is always accessible
• Can be used for GIS analysis on the web

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
Web Map/Layer Services

Feature Service

Tile Service
Acquiring Spatial Data

Download or access data from the internet
Acquiring Spatial Data

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.
Acquiring Spatial Data

Data Collection

GPS or surveying techniques
Acquiring Spatial Data

Digitizing

- Using GIS software to create vector data
- Trace features from aerial images and scanned based maps that have been georeferenced
Geography and Cartography Concepts
Space vs. Place

- **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
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)

- 557 lines,
- Total length 1890 km

1:24,000 scale (large scale)

- 11,338 lines,
- Total length 5559 km

20 times no. of lines
3 times total length of lines
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

Landsat Multispectral Scanner – 80m pixel

Landsat Thematic Mapper – 30m pixel

SPOT Multispectral Scanner – 20m pixel

SPOT Panchromatic Band – 10m pixel

Source: http://www.geog.ucsb.edu/~jeff/115a/militaryintelligence/scaleandresolution.html
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>
</tr>
<tr>
<td>1:100,000</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>1:250,000</td>
<td>250</td>
<td>125</td>
</tr>
<tr>
<td>1:500,000</td>
<td>500</td>
<td>250</td>
</tr>
<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

Coordinate Systems in GIS

Two types in GIS:

• **Geographic Coordinate Systems (GCS)**

• **Projected Coordinate Systems (PCS)**
Geographic Coordinate Systems

• Based on a *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 Coordinate Systems are Important

Three Map Projections Centered at 39 N and 96 W

Mercator
Lambert Conformal Conic

Un-Projected Latitude and Longitude

Peter H. Dana 6/23/97
Spatial Analysis and Geoprocessing

Spatial Analysis
• Process of examining the locations, attributes, and relationships of features in spatial data through overlay and other analytical techniques
• Addresses questions to gain useful knowledge by extracting or creating new information from spatial data

Geoprocessing
• Provide tools and framework for performing spatial analysis and managing geospatial data
• Allows for analysis workflows to be automated
Spatial Analysis and Geoprocessing

Spatial Measurements

• Coordinates
• Distance and Buffers
• Area
Spatial Analysis and Geoprocessing

Overlays

- Intersect, Union, and Spatial Joins
- Clipping and Erasing
Spatial Analysis and Geoprocessing

Spatial Patterns

• Geographic Distribution
• Density and Cluster Analysis
• Nearest Neighbor Analysis
Library GIS Workshops

Core GIS Workshops
• Geographic Information Systems 101: Understanding GIS
  – Thurs. Feb. 4 and Fri. April 1, 2 – 3 pm, room 314
• GIS for Research I: Tools, Concepts, and Geodata Management
  – Thurs. Feb. 11 and Fri. April 8, 2 – 4 pm, room 314
• Discovering GIS Data
  – Thurs. Feb. 18 and Fri. April 15, 2 – 3 pm, room 314
• GIS for Research II: Geoprocessing, Analysis, and Visualization
  – Thurs. Feb. 25 and Fri. April 22, 2 – 4 pm, room 314

Special Topic GIS Workshops
• Forthcoming...
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
Library Resources

• **Scholarly Commons Data 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)

• **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!

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University Library
jvwhit@illinois.edu

Please feel free to contact me for further assistance.