GIS Fundamentals: Ch.1 (pp. 1-20), Ch.2 (pp. 25-61)
Reading assignment: “Why GIS?” (on class web site)

Material presented this week contributes to the accomplishment of the following course goal:

<table>
<thead>
<tr>
<th>Goal 3</th>
<th>Use GIS to perform basic spatial data analysis</th>
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<tr>
<td>Goal 7</td>
<td>Construct a map that successfully communicates the desired information to a user</td>
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_Information obtained this week will further expose you to metadata and the standard information associated with CSDGM compliant metadata. It will give you a tool to search for data as well as describe your own data. You will also begin to work with GIS to conduct simple data analysis and develop a basic map._

After studying class notes and reading assignments, participating in class discussions, and conducting lab. 7, you should be able to:

- Explain the basic make up of a GIS
- Explain how attributes can be added to an attribute table in ArcGIS
- Modify the default display symbols used in ArcGIS to display a layer
- Develop simple and complex queries of an attribute table in ArcGIS
- Measure distances between points using ArcGIS
- Join attributes from one GIS shapefile to another
- Describe the basic map elements necessary to communicate the desired information to a map user.
- Use ArcGIS to construct a map that effectively communicates information to the intended user
- Explain each of the components listed in CSDGM
- Develop a metadata file for digital data consistent with CSDGM
What is GIS?

- Tool for making and using spatial information...

- **GIS**: A computer-based system to aid in the...
  - Collection
  - Maintenance
  - Storage
  - Analysis
  - Output
  - Distribution of spatial data & information

- Underlying key to all definitions of GIS are...
  - **Where**?
  - **What**?
Spatial Analysis....Definitions

This first one is painful & weak...

“A type of geographical analysis which seeks to explain patterns of human behavior and its spatial expression in terms of mathematics and geometry; that is, locational analysis.”

This second one is a little better...

- Analytical techniques to determine the...
  - spatial distribution (the “where” part) of a variable (the “what” part),
  - the relationship between the spatial distribution of variables, and/or
  - the locational association among variables of an area

- Spatial analysis is often referred to as modeling. It refers to the analysis of phenomena distributed in space & having physical dimensions, such as...
  - the location of,
  - the proximity to, or
  - the orientation of...

  ...objects with respect to one another; referenced or relating to a specific location on the Earth's surface.
Basic GIS Concepts

There are two basic types of map information:

**Spatial information** defines the location and/or shape of geographic features & their relationship to other features.

**Descriptive information** defines the characteristics of attributes of map features.
GIS

GIS and spatial analyses are concerned with...

- Absolute & relative location of features (the “where” part)
- And, the properties & attributes of those features (the “what” part)

*For example:*

Locations of important spatial objects such as streams & rivers may be delineated

- Each has descriptive attributes (*data dictionary*):
  - Stream size (class: first, second, third order etc.)
  - Flow rate – volume/time (average annual, monthly, daily, etc.)
  - Water quality (N, P, O, pH, dissolved organic matter, BOD, clarity, sediment load, etc.)

These data may be displayed/combine with: land use, impervious surface, watersheds, etc.

➤ To better understand river and watershed responses/sensitivities to societal and/or environmental pressures.

*Spatial Relationships Emerge*
Hence, the real power of a GIS is its ability to link spatial data and descriptive (tabular) data...

...and maintain geographic relationships between map features

Quote from a “GIS day” presentation last year...

“...we didn’t fully understand relationships in our data until we mapped their spatial patterns; then it was obvious.”
Basic GIS Concepts

Spatial data (map features) are stored in a GIS using coordinates to reference features on the ground.

**POINT**  Single coordinate \((X,Y)\) pair

**LINE**  Ordered sets of connected points (vertices)

**POLYGON**  Areas defined by sets of lines (vertices & nodes)

**Examples**

Points  →  Poles, manholes, sites, events

Lines  →  Roads, streams, railroads, contours

Polygons  →  Lakes, jurisdictions, soils, watersheds
Basic GIS Concepts: ArcGIS Jargon

ArcGIS (formerly Arc/Info & ArcView) uses many classes of features to represent specific types of geographic data: **Main ones in red**

- **ARC** - A digital line, which is a string of coordinate pairs
- **NODE** - Beginning/ending locations of an arc
- **VERTEX** - Points of direction change in an arc
- **POLYGON** - Area bounded by arcs, has labels
- **LABEL POINT** - Points with one coordinate pair
- **ANNOTATION** - Descriptive text used for display
- **DANGLE** - Portion of arc that extends beyond an intended intersection with a node
- **SNAP DISTANCE** - Opposite of dangle. Arc that falls short of intended node intersection

- **TIC** – Geographic control point for registration
- **ROUTE** – Lines to reference attributes or events
- **SECTION** – Defines parts of lines or routes
- **LINK** – Defines from/to in adjusting coordinates
- **EXTENT** – Coverage boundary limits
- **REGIONS** – Defines coincident polygon area
- **ISLAND** – Polygons within polygons that boarder no other polygons
Spatial Database

Definitions:
• Collection of spatial features, descriptive attributes, plus the relationships between them
• A database that is optimized to store & query data that is related to objects in space, including points, lines and polygons.

Attributes are used to define the characteristics of the geographic objects

Coordinates are used to define spatial location and extent of geographic objects
Attributes data are used to define non-spatial characteristics of an entity or object.

- **Nominal** - descriptive: color, veg. type, city name
- **Ordinal** - rank/order: high, mid, low, class-1, class-2
- **Interval/ratio** – numeric: weight, length, depth, percent

**LIGHT POLE**
dented, needs paint
poor, fair, good
height, diameter, percent rusted

Attributes are also commonly referred to as **ITEMS** or **VARIABLES**
Spatial Database: Topology

All map features in a GIS have **Topology** which defines spatial relationships...

- **Connectivity**
  - Lines connect to nodes

- **Area**
  - Connecting lines (closed loop) defines polygons

- **Contiguity**
  - Direction and RIGHT/LEFT side

Features can share endpoints

- **arc node topology**

Area features can share boundaries

- **polygon topology**

Line features can share segments with other line features

- **route topology**

Area features can overlap with other features

- **region topology**

Line features can share endpoint vertices with point features

- **node topology**

Point features can share vertices with line features

- **point events**
Data Models: Basic Topology

Points

Lines

Polygons

Point ID | X  | Y  |
---------|----|----|
Q        | 32.7 | 45.6 |
R        | 76.3 | 19.5 |
S        | 22.7 | 15.8 |
etc...

Line ID | Begin node | End node | Left poly | Right poly |
--------|------------|----------|-----------|------------|
11      | 1          | 4        | ...       | A          |
12      | 4          | 2        | ...       | A          |
52      | 2          | 3        | B         | A          |
etc...

Polygon ID | Lines
-----------|------------------
A           | 11, 12, 52, 53, 54
B           | 52, 53, 19, 15, 14, 13
Data Input Methods

Spatial databases in GIS may be created from:

• Digitizing
• Scanning
• Photogrammetry
• Satellite remote sensing
• Government archive data
• Tabular data
• GPS
If you trying to look for something….
It can be a pain to look for this “something” within just a specific area?

Science field-work offers many good examples:

- Often concerned with recording ocular estimates of stuff (*quantitative estimates*) within a certain radius of a point/transect or within zones around a point/transect.

- Given one has the appropriate input layers… **GIS** can help you know WHERE to look and WHAT areas have already been searched or quantified.

**GPS** is not strictly a spatial analysis tool. **GPS** is one methods to collect spatial features

- **GPS** precisely places or locates **points/lines/polygons** …That’s all!

- **GIS**, on the other hand, uses **GPS data** as an input layer to anchor spatial analyses…
GIS uses GPS data as an input layer to anchor spatial analyses.

Once we have the points/lines/polys in a GIS we can begin to explore questions....

Q: How much of total sidewalk area is lighted by existing poles?
Q: Is there a need for more light poles?
Q: What specific areas represent safety concerns?
Q: Could we get away with having higher intensity light bulbs?
Q: Theoretical sidewalk area covered by the stronger bulbs?
Q: Is it cheaper to simply install more poles?
ArcGIS (complex) – PFO (simple)
ArcGIS Map Layout

2 Key concepts in cartography and map layout & design are:

- Affective design
- Substantive design

Affective Design

- Relates to the map document as a whole
- Consider this the “artistic” decisions you make
- What is the ‘look’ or ‘feel’ of the map?
  - Historical
  - Modern
  - Crowded
  - Simple
ArcGIS Map Layout

2 Key concepts in cartography and map layout & design are:
- Affective design
- Substantive design

Substantive Design
- Relates to what you decide to shown on the map & for what purpose
- Colors used
- Font types
- Symbology
- Actual content

Thinking about how all your layout/design choices will support these overall concepts
Map Layout/Design Considerations

What is the map about?
Who is the map for?
How will the map be used?
Are there technical limits?

All essential for a good map

Some examples...

- **Map content**: thematic, reference, schematic
- **Audience**: general, specifically technical
- **Mode of map use**: moving vehicle, internet
- **Print device**: may not have same color range as your monitor
Layout Design: Technical Aspects

**BALANCE** ➔ Aspect of Substantive Design

How to divide and allocate your page?
How to arrange the various elements?

**MARGINS** ➔ May be a technical consideration

Different printers have different page limits

**WHITE SPACE** ➔ Is something missing?

**BOUNDING BOX** ➔ Affective Design

Make a big difference if the map is on a white background.
Don’t want the map to look like it is floating in space.

**ALIGNMENT** ➔ Try to avoid a random look.

These will have subtle but important influence on the success or failure of what the map is trying to communicate.
Layout Design: Technical Aspects

- Balance
  - Margins
  - White space
  - Bounding boxes
  - Alignment

[Diagram showing unbalanced and balanced layout]
Map Components

- Titles
- Legends
- Scale indicator
- North arrows
- Detail / overview map
- Grids & graticules
- Text blocks
- Finder map
- Supporting graphics
Capabilities of ArcGIS

http://www.esri.com/software/arcgis/about/desktop-extensions.html
ArcGIS 3D Analyst provides advanced visualization, analysis, and surface generation tools. Using ArcGIS 3D Analyst, you can view large sets of data in three dimensions from multiple viewpoints, query a surface, and create a realistic perspective image that drapes raster and vector data over a surface.

With ArcGIS 3D Analyst, you can:

- Analyze terrain data to determine what can be seen from different observation points.
- Model subsurface features such as wells, mines, groundwater, and underground networks and facilities.
- View and analyze impact zones from blasts and military threats.
- Determine optimum facility placement or resource location.
- Share 3D views, animations, and analyses with stakeholders and decision makers.
- Create a 3D virtual city to support planning and maintenance.

Who Benefits from 3D GIS
A 3D perspective creates a realistic simulation of a project, environment, or critical situation to help a variety of clients plan and prepare for and proactively mitigate potential issues.

- City planners and developers can visualize the impact of proposed projects and share insights with community stakeholders.
- Mining and geoscientists can examine subsurface structures and calculate volumes.
- Facility managers can create and maintain building, infrastructure, and utility networks.
- Civil engineers can perform line-of-sight and shadow analyses for buildings, cell towers, and utility infrastructure.
- Police and security personnel gain more complete situational awareness.
- Military personnel can perform realistic mission and flight path analyses of potential threats.

ArcGIS 3D Analyst is also available as an extension for ArcGIS for Server and ArcGIS Engine.
ArcGIS Geostatistical Analyst provides a suite of statistical models and tools for spatial data exploration and surface generation. Using ArcGIS Geostatistical Analyst, you can create a statistically valid prediction surface, along with prediction uncertainties, from a limited number of data measurements.

With ArcGIS Geostatistical Analyst, you can:

- Explore data variability and spatial relationships, look for unusual data values, and examine global and local trends.
- Utilize multivariate analysis to create optimal statistical models to produce reliable maps of predictions, prediction errors, quantiles, and probabilities for improved decision making.
- Modify model parameters interactively or automatically optimize them using cross validation.
- Determine optimal locations to create or update a monitoring network.
- Prepare for worst-case scenarios by simulating many possible realizations of an environmental process.

ArcGIS Geostatistical Analyst helps you examine real-world issues in:

- Atmospheric data analysis
- Petroleum and mining exploration
- Environmental analysis
- Precision agriculture
- Fish and wildlife studies

ArcGIS Geostatistical Analyst enables you to take advantage of these tools and techniques in an interactive graphical user interface (GUI) and as web services.

ArcGIS Geostatistical Analyst is also available as an extension for ArcGIS for Server.
**ArcGIS Spatial Analyst** provides a range of spatial modeling and analysis tools. Using ArcGIS Spatial Analyst, you can

- Create, query, map, and analyze cell-based raster data.
- Perform integrated raster/vector analysis.
- Derive new information from existing data.
- Query information across multiple data layers.
- Fully integrate cell-based raster data with traditional vector data sources.

Examples of the types of analysis that you can do with ArcGIS Spatial Analyst include

- Find suitable locations.
- Calculate the accumulated cost of traveling from one point to another.
- Perform land-use analysis.
- Predict fire risk.
- Analyze transportation corridors.
- Determine pollution levels.
- Perform crop yield analysis.
- Determine erosion potential.
- Perform demographic analysis.
- Conduct risk assessments.
- Model and visualize crime patterns.

ArcGIS Spatial Analyst is also available as an extension for ArcGIS for Server and ArcGIS Engine.
Hillshading computes surface illumination as values from 0 to 255 based on a given compass direction to the sun (azimuth) and a certain altitude above the horizon (altitude).
This map of Mount Saint Helens shows how elevation can be combined with hillshading to create a map that displays elevation and the shape of the surface simultaneously.
Slope is a measure of the steepness of a surface and may be expressed in either degrees or percent of slope. In this example, the red cells show steep areas and the green cells show flat areas.
In this example, red represents slopes facing north and green shows slopes facing south. Gray represents flat slopes.
Viewshed analysis calculates the area on a surface visible from one or more observation points. Parameters typically can be set to control the vertical and horizontal field of view, the height of the observer and target cells, and the view radius.
ArcGIS Spatial Analyst

Map Algebra

Vegetation + Prey habitat + Landform

Canada Lynx habitat

Map Algebra expression:

\[ [\text{Vegetation}] + [\text{Prey habitat}] + [\text{Landform}] \]

Output raster:

LynxHabitat
**ArcGIS Spatial Analyst**

### Arithmetic Operators
- + Addition
- - Subtraction
- * Multiplication
- /, DIV Division
- MOD Modulus
- - Unary minus

### Relational Operators
- ==, EQ Equal
- ^=, <> Not equal
- <, LT Less than
- <=, LE Less than or equal
- >, GT Greater than
- >=, GE Greater than or equal

### Logical Operators
- DIFF Logical difference
- IN {list} Contained in list
- OVER Replace

### Combinatorial Operators
- CAND Combinatorial And
- COR Combinatorial Or
- CXOR Combinatorial Xor

### Boolean Operators
- ^, NOT Logical complement
- &, AND Logical And
- |, OR Logical Or
ArcGIS Network Analyst provides network-based spatial analysis, such as routing, fleet routing, travel directions, closest facility, service area, and location-allocation. Using ArcGIS Network Analyst, you can dynamically model realistic network conditions, including one-way streets, turn and height restrictions, speed limits, and variable travel speeds based on traffic. You can easily build networks from your GIS data by using a sophisticated network data model.

With ArcGIS Network Analyst, you can:
- Find shortest routes.
- Produce the most efficient routes for a fleet of vehicles that must visit many locations.
- Use time windows to limit when vehicles can arrive at locations.
- Locate closest facilities.
- Determine optimal locations for facilities by performing a location-allocation analysis.
- Define service areas based on travel time or distance.
- Create a network using your existing GIS data.
- Generate a matrix of network travel costs from each origin to all destinations.

ArcGIS Network Analyst is also available as an extension for ArcGIS for Server and ArcGIS Engine.
**ArcGIS Tracking Analyst** extends the time-aware capabilities of the ArcGIS system with advanced functions to let you view, analyze, and understand spatial patterns and trends in the context of time. By providing tools for time-dependent symbolization and time-based analysis, ArcGIS Tracking Analyst automates and enables the tracking and discovery of time-related trends and patterns.

With ArcGIS Tracking Analyst, you can

- Create geofences to detect when people, assets, or vehicles go outside an allowable area or enter a restricted area.
- Be notified of important events and report on patterns related to time and space, based on rules you define.
- Monitor your mobile resources and visualize patterns in their movement.
- Identify trends over time and make better decisions with advanced time-based symbols and analysis tools.

When combined with Tracking Server, ArcGIS Tracking Analyst can be used to create a real-time GIS tracking system to support

- Fleet management and vehicle tracking
- Sensor network monitoring
- Emergency response
- Resource management

ArcGIS Tracking Analyst is also available for ArcGIS Engine.
Prepare Metadata

Materials Needed

- One laptop/group
- Copy of data dictionary from lamp pole data

Major

Identification Information
data set title, area covered, keywords, purpose, abstract, access and use restrictions

Data Quality Information
horizontal and vertical accuracy assessment, data set completeness and lineage

Spatial Data Organization Information
raster, vector, or an indirect (e.g. address) link to location

Spatial Reference Information
lat/long, coordinate system, or map projection

Entity and Attribute Information
definitions of the attributes of the data set

Distribution Information
distributor, file format of data, off-line media types, on-line link to data, fees

Metadata Reference Information
who created the metadata and when

Citation Information
originator, title, publication date, publisher

Minor

Time Period Information
single date, multiple dates, range of dates

Contact Information
contact person and/or organization, address, phone, email
Dodge County GPS Net

Metadata:

- Identification Information
- Data Quality Information
- Spatial Reference Information
- Distribution Information
- Metadata Reference Information

Identification Information:

Citation:
Originator: Dodge County
Publication_Date: 1993
Title: Dodge County GPS Net
Publication Information:
Publication Place: Juneau, WI
Publisher: Dodge County Survey and Description Department

Description:
Abstract:
In 1991, Dodge County was part of a three county consortium effort to regionally densify the Wisconsin HARN (High Accuracy Reference Network). The project was done in cooperation with the Wisconsin Dept. of Transportation and Rock and Jefferson Counties. Following the "Request for Proposal (RFP) on the Establishment of a High Precision Geodetic Network Using Global Positioning System (GPS) Technology for Dodge, Jefferson, and Rock Counties, Wisconsin" (November 11, 1992), Dodge County developed a locally densified geodetic network at the primary (5-1ppm stations), secondary (14-2ppm stations), and tertiary (57-4ppm stations) levels. THE RESULTING POSITIONS COMPRIS THE DATA DOCUMENTED HERE.

Purpose:
Dodge County GPS Net geodetic positions are intended to be used as the primary spatial reference system for surveying and mapping activities in Dodge County.

Time Period of Content:
Time Period Information:
Single Date Time:
Calendar Date: 1993
Currentness Reference: Date of GPS observations

Status:
Progress: Complete
Maintenance and Update Frequency: As needed

Spatial Domain:
Bounding Coordinates:
West Bounding Coordinate: 89.0095
East Bounding Coordinate: 88.4802
North Bounding Coordinate: 43.8336
South Bounding Coordinate: 43.1948

Keywords:
Theme:
Theme Keyword Thesaurus: None
Theme Keyword: geodetic control
Theme Keyword: geodetic network
Theme Keyword: HARN

Theme Keyword Thesaurus: Wisconsin Land Information Program Thesaurus
Theme Keyword: Foundational Elements
Theme Keyword: Geographic Frameworks
Theme Keyword: Geodetic Reference Systems
Theme Keyword: Geographic Control Data

SAVE YOUR DATA OFTEN !!
Pete's GPS Data for Light Poles

Metadata:

- Identification Information
- Spatial Data Organization Information
- Spatial Reference Information
- Entity and Attribute Information
- Distribution Information
- Metadata Reference Information

**Identificatoin Information:**
- Citation Information:
  - Originator: Pete Walter
  - Publication Date: Unknown
  - Title: Pete’s GPS Data for Light Poles
  - Edition: 1.0
  - Series Information:
    - Series Name: What ever I entered last time
    - Issue Identification: V1.0
  - Publication Information:
    - Publication Place: ISU
    - Publisher: NREM

**Description:**
- Abstract:
  - GPS position collected as part of a GPS-GIS class exercise demonstrate the basics of satellite navigation and positioning. In this class 27 light pole locations were collected using "point" location fixes. The lab was designed to have students collect data, return to lab and differentially correct position errors due to UERE problems. Finally, students produced two maps: one in Pathfinder Office and the other in ArcGIS.

**Purpose:**
- Learning exercise for NREM446/546 at ISU

**Time Period of Content:**
- Single Date/Time:
  - Calendar Date: 20120220
  - Time of Day: 083030

**Currentness Reference:**
- Required element.

**Status:**
- Progress: Required element
- Maintenance and Update Frequency: Required element

**Spatial Domains:**
- Description of Geographic Extent: Campus Greens at ISU

**Bounding Coordinates:**
- West_Bounding_Coordinate: -93.64793611
- East_Bounding_Coordinate: -93.643675
- North_Bounding_Coordinate: 42.02976944
- South_Bounding_Coordinate: 42.02786389

**Bounding Altitudes:**
- Altitude_Minimum: 296.317
- Altitude_Maximum: 288.312
- Altitude_Distance Units: meters

**Keywords:**
- Theme_Keyword_Thesaurus: GPS data
- Theme_Keyword: POINT
- Theme_Keyword: Lamp Post
- Theme_Keyword: Campus Greens
- Theme_Keyword: NREM446/546 class
- Theme_Keyword: Iowa State University

**Place:**
- Place_Keyword_Thesaurus: Central Campus
- Place_Keyword: Campus Greens
- Place_Keyword: ISU

**Access Constraints:**
- Extremely Limited

**Use_Constraints:**
- Can make your eyes spin in your head

**Data Set Credit:**
- Pete Walter

**Security Information:**
- Security_Classification_System: Top secret
- Security_Classification: Sensitive
- Security_Handling_Description: Use rubber gloves

**Native Data Set Environment:**

**Analytical Tool:**
- Analytical Tool_Description: Sometimes a hammer

**Tool Access Information:**
- Tool Access Instructions:

**Spatial Data Organization Information:**
- Direct_Spatial_Reference_Method: Point

**Spatial Reference Information:**
- Horizontal_Coordinate_System_Definition:
  - Plane:
    - Grid_Coordinate_System_Name: Universal Transverse Mercator
    - Universal_Transverse_Mercator:
      - UTM_Zone_Number: 15
      - Transverse_Mercator:
        - Scale_Factor_at_Central_Meridian: 0.9999
        - Longitude_of_Central_Meridian: -93.0000
        - Latitude_of_Projection_Origin: 0
        - False_Easting: 500000.0
        - False_Northing: 0
  - Planar_Coordinate_Representation:
    - Planar_Coordinate_Encoding_Method: coordinate pair
    - Coordinate_Representation:
      - Abscissa_Resolution: 1
      - Ordinate_Resolution: 1
    - Planar_Distance Units: meters

**Geodetic Model:**
- Horizontal_Datum_Name: North American Datum of 1983
- Ellipsoid_Name: Geodetic Reference System 80
- Semi-major Axis: 6378137
- Denominator of Flattening Ratio: 298.2572210085