Introduction to Geographic Information Systems

I. Basic Terminology
  A. Geographic Information Systems (GIS)
    1. Preliminary Ideas
      a. maps = models of the Earth
        (1) Traditional maps - paper drawings / models of the Earth
      b. map distribution = spatial distribution
      c. computers + digital information
      d. computer assisted cartography (CAC) - digital maps
      e. computer assisted drafting (CAD) - digital drawings
    2. Definition
      a. Computerized data input system that collects and processes spatial map data
      b. A data storage and retrieval system that organizes spatial data (database)
      c. A data manipulation and analysis system (mathematical and statistical tasks)
      d. Report subsystem (graphic output = digital map, database tables)

GIS = "capture, store, query, analyze, and display geographic data"

  B. Other Terminology
    1. Cartographic process - data collection and map compilation
    2. Map Features
      a. points
      b. lines
        (1) straight line segments - between two points
        (2) polylines - multiple segmented lines
      c. polygons - lines that enclose areas
    3. Map Layers
      a. layers of spatial data that form "tracing overlays" on top of one another
        (1) e.g. geology, vegetation, buildings, soil, etc.
      b. examples of layers or themes or coverages for any given map region
        (1) topography
        (2) geology
        (3) population density
        (4) roads
        (5) streams
        (6) vegetation
        (7) soils.... etc.

    4. Examples of Digital Data Sources
      a. Digital Line Graphs (DLG) -
      b. Digital Elevation Models (DEM) - grid data over space, eg. elevation
      c. Digital Photoquadrangles

5. Example GIS measurements from data
    a. line lengths
    b. polygon perimeters
    c. polygon areas
    d. spatial density (e.g. housing density per square mile)
    e. frequency (the number of occurrences)
    f. map vs. ground distances
    g. angles between lines
6. LIS = land information systems
7. GPS = global positioning systems - satellite-based location system
8. Geodesy - measurement and mapping of the Earth's surface
    a. Geodetic framework - position and elevation of points on the earth's surface

II. Introduction to Spatial Data

A. Spatial Coordinate System
1. Longitude and Latitude
    a. Angular coordinate system relative to the Equator and Poles
2. UTM = Universal Transmercator (northings and eastings in meters)
    a. Linear cartesian coordinate system relative to North-South and East-West baselines- measured in meters
3. State Plane = "State Plane" (northings and eastings in feet)
    a. Linear cartesian coordinate system relative to North-South and East-West baselines- measured in feet
4. Map Projection
    a. Problem: the Earth is 3-D and spherical while paper maps and computer screens are 2-D
        (1) How to project a 3-D object to a 2-D surface?
    b. Multiple map layers must be in the same projection if they are to appropriately line-up in space
        (1) e.g. can't overlay a geologic map in State Plane ontop of a soil map in Lat-Lon

B. Types of Spatial Data
1. Discrete Features - isolated map entities that are not connected
    a. e.g. a water well = discrete point feature
    b. e.g. a road = discrete polyline feature
2. Continuous Features - spatially distributed data across the map
    a. e.g. rainfall / precipitation, bedrock geology, topography / elevation
3. Map Features
    a. points, lines, polygons
4. Feature Attributes
    a. data attached to points, lines, polygons
        (1) e.g. a point rainfall collection station could have an average annual precipitation attribute attached to it.

C. Data Models
   1. Vector data model - points and their x,y map coordinates are used to create point, line, and polygon features
      a. Topological Vector Data - an expression of the spatial relationships between map features
         (1) e.g. vector points define a line with a start point, end point, left side, and right side
      b. Non-Topological Data - map features that do not have topology associated with them
      c. ESRI GIS Software Terms
         (1) Coverage = topological vector map data
         (2) Shapefile = non-topological vector map data
   2. Raster data model - rectangular grid cells are used to represent spatial features
      a. e.g. rainfall amounts in a watershed

D. Attribute Data
   1. attribute data - data that describe the characteristics of spatial features
      a. e.g. a line that represents a road is attributed with the route number and type of highway (2 lane, interstate, etc.)
   2. Managing Attribute Data
      a. Georelational database - a collection of tables that are related to one another by common index attributes
         (1) functions: search, data retrieval, data editing, creation of tabular reports
         (2) Linking Tables - tables linked to one another by common attributes or identification

III. GIS Operations

A. Spatial Data Input
   1. Create Database
   2. Digitize map features in relation to a map projection and coordinate system
   3. Digitizing - process of capturing spatial data on the computer
      a. Digitizing tablet
      b. On-Screen Digitizing - "heads up" digitizing
      c. calibrating the digital feature with real-world geographic coordinates
   4. GPS as a tool for capturing spatial data

B. Attribute Data Management
   1. Using georelational database editor to enter attribute data to map features
   2. Database Tables (table = cells in rows and columns)
      a. Columns = Fields
      b. Rows = Records
   3. Key Fields
      a. Columns of data that can be used to link multiple tables together

C. Data Display
   1. Digital Map / Cartographic Display
   2. Tabular Data Display

D. Data Exploration
    1. data-centered query and analysis
        a. query = asking a question of the data
    2. Identify general trends, distribution, and relationships between data
E. Data Analysis
    1. mathematical and statistical operations on spatial data
        a. e.g. measure land slope from an elevation model
        b. measure areas of bedrock geology polygons
    2. Spatial Interpolation
        a. Using discrete control points to estimate a continuous distributon of data
            (1) e.g. contouring elevation data to make a topographic map
        b. Geostatistics

F. GIS Modeling / Spatial Modeling
    1. Using a given data set to model changes in spatial trends through time and space
    2. Using existing data to create new data

IV. GIS and Spatial Database Functions

A. Purpose: to use map feature to call and retrieve data about a given area or map object.
B. Database Query
    1. Asking questions about attributes in a spatial database
    2. Geographic searching is critical to GIS database queries

C. Examples of spatial database queries that can be accomplished with GIS

    1. Find all homes in the city of Portland that have the following attributes: they are located within 50 ft of a fire hydrant, are painted red, are situated within 500 feet of an active fault zone, and have median household incomes of greater than $50,000.00
    2. Find all map areas that are associated with hillslope gradients greater than 25 degrees

    3. What is the total land area on the map that is underlain by alluvial deposits of the Willamette River?

V. GIS Map Types
A. Dot Maps or Symbol Maps
    1. e.g. locations of state capitols around the U.S.
B. Line Maps
    1. e.g. road maps
    2. stream network maps
    3. topographic (contour) map
C. Area Maps
    1. isohyet map (map showing areas of equal rainfall)
    2. land use map (map showing areas of similar land use)
D. Volume Maps

1. 3-D models of the Earth's surface

VI. Examples of Advanced Analytical Techniques
   A. Hydrologic modeling and prediction
   B. Statistical analysis of spatial data
   C. Network analysis (choosing paths of lowest cost or most efficient routes)