Lecture One: Overview of Course, GIS Principles, Elements of Maps, ArcGIS Basics

1. Overview of Course

- Syllabus/Lectures/Labs/Homeworks/Project
- Other GIS courses: 11.204, 11.220, 11.521, IAP miniclasses, Harvard, BU.
- Student background

2. GIS Principles

2.1 Geographic information

- is information about places—spatial dimension
- 80% of all information include spatial component - how should one embed location in data
- knowledge about both where something is and what it is - with query capability in both directions

- geographic resolution
  - very detailed
    - information about the locations of all buildings in a city
    - information about individual trees in a forest
  - very coarse
    - climate of a large region
    - population density of an entire country
• characteristics
  o often relatively static-- e.g., GPS coordinates of fixed features
    • natural features and many features of human origin don't change rapidly
    • static information is easier to portray on a static paper map
  o can be very voluminous
    • a terabyte ($10^{12}$ bytes) of data is sent from a single satellite in one day
    • gigabytes (gigabyte = $10^9$ bytes) of data are needed to describe the US street network

Abstraction--Geometrical Representation

• Model the **boundaries** of spatial objects (vector data models)

  • Point--a single location is enough
    • MBTA Stops
    • Is Boston a point?--At different scales or for different purposes, Boston could be a point or polygon.
  • Line--only one dimension needs to be represented
    • Street centerline, MBTA Railroad track, ridgeline, bux route
    • How does it matter if street is modeled as centerline or as void between blocks?
  • Polygon--2D planar surfaces
    • Cambridge border, central square boundary, census tract, parcel, ...
    • What about river boundary, edge of ocean (at high tide?)
  • Beyond planar surfaces - terrain models, 3D CAD models, ...

• Model the **space** that **contains** things (raster data models)

  • 30m x 30m grid cells for Landsat image - classified based on predominate land use within each cell
  • 6 inch pixels for color orthophotos developed from aerial photography
  • 3 km x 3km x 1 km (height) volumes for meterological modeling

2.2 Five examples to view and discuss: which are GIS? what to learn? how to add your own data/analyses?

• Private sector mapping services
  o Mapquest or Google-Maps to find a location and generate a street map. www.mapquest.com, maps.google.com
  o Google-Earth (and Keyhole, Digital Earth, etc.) to navigate and 'fly' over the earth: earth.google.com

• Spatial analysis using commercial GIS software
  o ArcGIS to analyze the demographics and economic development potential of Appalachia - we'll use ArcGIS
Web services using open-source (LAMP) tools
  o location-based services: tracking WiFi usage on campus: iSpots, Wireless Technology at MIT [http://isspots.mit.edu/]

2.3 Geographic information systems

2.3.1 Definition

GIS is a computer-based information system that enables capture, modeling, manipulation, retrieval, analysis and presentation of geographically referenced data. (Worboys, 1997)

Other definitions of GIS

- A container of maps in digital form.
- A computerized tool for solving geographic problems.
- A spatial decision support system.
- A tool for revealing what is otherwise invisible in geographic information
- A tool for automatically performing operations on geographic data.

2.3.2 Components of GIS

- Hardware, Software, Data, People, Procedure, Network (Internet)

- GIS hardware is like any other computer (nothing special about the hardware)
  o keyboard, display monitor (screen), cables, Internet connection

  o with some extra components perhaps
  - large monitor, disk drive, RAM
  - maps come on big bits of paper
    - need specially big printers and plotters to make map output from GIS
    - need specially big devices (digitizers, scanners,...) to scan and input data from maps to GIS

- software

  o ESRI [http://www.esri.com]
  o Intergraph Corporation [http://www.intergraph.com]
  o Autodesk [http://www.autodesk.com]
• what is important is the kind of information that's stored and analyzed
  o representing and managing information about what is where
    ▪ the contents of maps and images
  o special functions that work on geographic information, functions to:
    ▪ display on the screen
    ▪ edit, change, transform
    ▪ measure distances, areas, proximity, adjacency
    ▪ combine maps of the same area together
  o useful functions can be much more sophisticated
    ▪ keep inventories of what is where
    ▪ manage properties, facilities
    ▪ judge the suitability of areas for different purposes
    ▪ help users make decisions about places, to plan
    ▪ make predictions about the future

2.3.3 Example GIS Applications

• Resources inventory (what is available at where?)
• Network Analysis (How to get to a place in the shortest amount of time?)
• Location Analysis (Where is the best place to locate a shopping mall?)
• Terrain Analysis (What is the danger zone for a natural disaster? Visibility analysis)
• Spatio-Temporal Analysis (Land use: what has changed over the last twenty years, and why?)

Transportation applications

• a state department of transportation needs to
  o store information on the state of pavement everywhere on the state highway network
  o maintain an inventory of all highway signs
  o analyze data on accidents, look for 'black spots'
• a traveling salesperson needs
  o a system in the car for finding locations, routes
• a delivery company, e.g. Federal Express, UPS, needs to
  o keep track of shipments, know where they are
  o plan efficient delivery routes
• a school bus operator needs to
  o plan efficient collection routes
• a transit authority needs to
  o know where transit vehicles are at all times
• studies have shown substantial savings when routes and schedules are managed using GIS
Public Policy applications

- Education
- Health and Safety
- Public Service
- Land Use and Transportation interactions
  Term Project Example: Measuring Diversity of Land Use Pattern and its Relation to Transportation Mode Choice

2.3.4 Systems, science and studies

- **what does it mean to be "doing GIS"?**
- *using the tools* of Geographic Information Systems to solve a problem
  - such as those in the previous examples
  - a GIS project might have the following stages:
    1. define the problem
    2. acquire the software (and the hardware?)
    3. acquire the data
    4. clean the database
    5. perform the analysis
    6. interpret and present the results

- **data models and database management**
  - storing/retrieving/manipulating attributes of spatial objects
  - spatial analyses can be complex and computing-intensive with enormous amounts of data

- **helping to build the tools**
  - adding to existing geographic information technologies
  - helping to invent or develop new ones

- **studying the theory and concepts** that lie behind GIS and the other geographic information technologies
  - thus GIS = Geographic Information Science

- Forer and Unwin (1997) add a fourth variant
  - Geographic Information Studies
    - are studies of the societal context of geographic information
      - the legal context
      - issues of privacy, confidentiality
      - economics of geographic information
3. Elements of the Map

- Scale (Distance on the map compared with distance on the earth)
- Symbolization
- Projection

Scale

- Ratio Scale, 1:10,000, or 1:100,000 or 1/100,000
- Verbal Scale:
  - One inch represents 2,000 feet (1:24,000).
  - One centimeter represents 20 kilometers (1:2,000,000)
- Graphic Scale:
  - Scale bar: Less precise but easily interpreted (for constant scale map projections)
  - Particular useful for publishing maps in newspapers, magazines or online.

Symbolization

- Reality vs. Representation
- Visual Variables: Size, color, shape, orientation, texture
- Use contrasting symbols to portray geographic differences
  - For qualitative differences--Use shape, texture and hue (e.g., land use types).
  - For quantitative differences--Use size to show variation in amount or count (e.g., population, No. of crime),
  - Use graytone or hue to show differences in ratio or intensity --(e.g., proportion of household in poverty, population density).

Geographic Reference System & Projection

- Geographic Reference System: Latitude and Longitude
- In North America, it is called North American Datum of 1983 (NAD83)
- What do Latitude and Longitude mean?
  - Two points on the same longitude, separated by one degree of latitude are 1/360 of the circumference of earth apart, or about 111 km apart.
  - One minute latitude is 1.86 km—nautical mile
  - One second latitude is 30 m.
- For the same latitude, one degree of longitude corresponds to different distance depends on the latitude.
- Map Projections
  - Map projections transform the curved, 3-D surface of the planet onto a flat, 2-D plane.
  - Map projections distort map scale but can preserve area, or angles, etc. (for small areas).
Map 'Layouts' include 'metadata' needed to interpret the map:

- Title, Legend, Scale Bar, North Arrow, Data sources,
- Name or organization
- Date

4. ArcGIS Basics--Lab Exercise 1 (Mapping Cambridge home sales and household income)

I. Setting Up a Work Environment

- Start an ArcGIS
- ArcMap Interface

II. Getting Data Into ArcMap

- Data Frame Properties: Name, Units (Map, Display)
- Layer Property
- Tool in/out
- Attribute Data

III. Basic Map Making

- Simple Symbolization
- Thematic Symbolization

IV. Saving Your Work and Printing Output