Massachusetts Institute of Technology
Department of Urban Studies and Planning

11.520: A Workshop on Geographic Information Systems
11.188: Urban Planning and Social Science Laboratory

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

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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
    - 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
    - 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,<![endif]> 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
    - Mapquest or Google-Maps to find a location and generate a street map. www.mapquest.com , maps.google.com
    - Google-Earth (and Keyhole, Digital Earth, etc.) to navigate and 'fly' over the earth: earth.google.com
- Spatial analysis using commercial GIS software
    - ArcGIS to analyze the demographics and economic development potential of Appalachia - we'll use ArcGIS

- Web services using open-source (LAMP) tools
    - commute sheds and labor sheds for a community (database driven web pages ia servers running Linux/apache/mysql/postgresql/minn-map-server/php): Mapping Metro Boston Growth http://subway.mit.edu/umi/ctpp/
    - location-based services: tracking WiFi usage on campus: iSpots, Wireless Technology at MIT (http://ispots.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)
    - keyboard, display monitor (screen), cables, Internet connection

    - 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

    - ESRI (http://www.esri.com)
    - Intergraph Corporation (http://www.intergraph.com)
    - Autodesk (http://www.autodesk.com)
    - Caliper: GIS Software, Mapping Software (http://www.**caliper**.com)

- what is important is the kind of information that's stored and analyzed

    - representing and managing information about *what* is *where*
        - the contents of maps and images
    - 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
    - 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
    - store information on the state of pavement everywhere on the state highway network
    - maintain an inventory of all highway signs
    - analyze data on accidents, look for 'black spots'
- a traveling salesperson needs
    - a system in the car for finding locations, routes
- a delivery company, e.g. Federal Express, UPS, needs to
    - keep track of shipments, know where they are
    - plan efficient delivery routes
- a school bus operator needs to
    - plan efficient collection routes
- a transit authority needs to
    - 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
