Conceptual Models

Characterized all features or phenomena as:

- **Discrete objects**: e.g., wells, roads, rock bodies, etc.
- **Object-based models**
- **Continuous phenomena**: e.g., gravity, topography, temperature, snowfall, soil pH, etc.
- **Field-based models**

Outline

- ESRI Software Family
  - ESRI Object Data Models
    - History
    - Data Organization – Physical Models
      - Coverage
      - Shapefile
      - Geodatabase
  - Data Capture
    - Digitizing
    - “Heads Down”
    - “Heads Up”
    - Building Topology

Some ESRI History...

<table>
<thead>
<tr>
<th>ESRI</th>
<th>Arc/Info</th>
<th>ArcView</th>
<th>ArcGIS Desktop</th>
<th>ArcGIS Pro</th>
</tr>
</thead>
<tbody>
<tr>
<td>Versions</td>
<td>1-7</td>
<td>1-3.2</td>
<td>8.0 – 10.7</td>
<td>1.0-2.4</td>
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<td>Data Model</td>
<td>Coverage</td>
<td>Shapefile</td>
<td>Geodatabase</td>
<td>Cloud, Geodatabase</td>
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<tr>
<td>O.S.</td>
<td>Unix, PC DOS</td>
<td>Windows</td>
<td>Windows</td>
<td>Windows</td>
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<td>Scripting Language</td>
<td>Arc Macro Language (AML)</td>
<td>Avenue Scripting</td>
<td>Vis-Basic for Appl. (VBA), Python</td>
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<td>Database Software</td>
<td>Proprietary; Arc Tables</td>
<td>DBase</td>
<td>M.S. Access; ArcSDE for Oracle, etc.</td>
<td>? Cloud ?</td>
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</table>
**ArcGIS Licensing Levels**

- **Basic** – Entry level; make maps, do queries, some spatial analysis, some editing (shapefiles, personal geodatabases) – included with GTK ArcGIS Desktop
- **Standard** – midlevel; advanced editing, multi-user geodatabases; more tools in toolbox
- **Advanced** – full functionality; control of “all aspects of data building, modeling, analysis and map display

**UT D.G.S. licenses**

**ArcGIS Extensions**

- **ArcView, ArcEditor, and ArcInfo**
  - Advanced raster modeling
  - Arc GRID calculator with Arc GRID algebra
  - VBA for raster analysis

- **ArcGIS Spatial Analyst**
  - ArcScene™ real-time interactive three-dimensional scenes
  - Scenes views in ArcCatalog
  - Three-dimensional modeling tools
  - Spatial Analyst tools

- **ArcGIS 3D Analyst**
  - ArcScene™ real-time interactive three-dimensional scenes
  - Scenes views in ArcCatalog
  - Three-dimensional modeling tools
  - Spatial Analyst tools

- **Geostatistical Analyst**
  - Advanced kriging and surface modeling
  - Exploratory spatial data analysis tools
  - Probability, density, and trend mapping

**ArcInfo only**

- ARCGIS program in ArcInfo workstation
- ARCGIS commands in Arc program
- ARC TIN™ commands in Arc program
- Surface modeling

**Others available:** Network, Tracking, Survey, Maplex, (ERDAS Image Analyst)

**ESRI Data Models**

- **Topologic:**
  - ArcInfo - Coverage
  - ArcInfo "EOO" – export format for coverage
  - ArcGIS - Geodatabase

- **Non-Topologic:**
  - ArcView (legacy) - Shapefile
Early ESRI Data Models

- **Coverages**
  - Developed for workstation
  - Arc/Info ~ 1980
  - Complex structure, proprietary format
  - Attributes in Info tables

- **Shapefiles**
  - Developed for ArcView ~ 1993
  - Simpler structure in public domain
  - Attributes in dBase (.dbf) tables

Geographic coordinates and attributes are stored in separate but linked files.

Data Organization

- **Coverage**
  - Data split between coverage and INFO folders
  - Common boundaries between polygons stored once
  - Topology explicitly stored
  - Planar graph maintained
  - As in previous lecture

- **Shapefile**
  - Data divided among three or more files (.shp, .shx, .dbf, .sbx, .sbn, et al.)
  - Common boundaries between polygons stored twice
  - Topology created on-the-fly
  - Planar graph not required

Folder/File Organization

- **Coverage**
  - One feature shape (as points OR lines OR polygons) per file = “SHAPEFILE”
  - Many related features (as points AND lines AND polygons) per file = “COVERAGE”

- **Shapefile**
  - Geology.shx
  - Geology.dbf
  - Geology.prj

ArcCatalog: Workspace>Coverage>Feature Class

Data Organization: Coverage in Windows Explorer and ArcCatalog

Feature Classes

Arc Catalog

Windows Explorer
Feature Class

- A collection of geographic objects with the same geometry (point, line, polygon) that share the same attributes.
- A shapefile contains one feature class
- A coverage can contain many feature classes

ArcInfo Coverage

- An integrated, homogeneous set of feature classes (pts., lines, polygons) stored together
- Feature classes unified by a theme, e.g. hydro
- Spatial (coordinate) data stored in binary files;
- Attributes and topologic data stored in INFO tables
- Stored within a “Workspace”

ArcInfo Coverages can contain:

- Primary feature classes:
  - Points, with attributes in PAT (point attribute table)
  - Nodes, with attributes in NAT
  - Arcs, with attributes in AAT
  - Polygons, with interior label points and attributes in PAT

Coverages feature classes can contain:

- Secondary features:
  - Tics – registration points for digitized data
  - Annotations – text for map
  - Links – vectors used for adjusting local area to known locations (spatial adjustment)
Covers can also contain:

- Composite features:
  - Routes – collections of Arcs with measurement system
  - Regions – collections of polygons; adjacent, noncontiguous or overlapping

**Shapefile format**

- Simpler than coverage; doesn’t store topology
- Feature classes stored independently i.e. points, lines and polys. stored in physically separated files (e.g. no shared INFO table)
- For each type, spatial data stored in a .shp file, attribute data in a .dbf table.
- "Null" or "No Data" numerical values not supported in attribute tables

**Shapefiles in ArcCatalog/Explorer**

- Folder / Shapefile
- Three or more files per feature class

**Shapefile feature class types:**

- Point, Multipoint
- Polyline (line with several paths)
- Polygon
  - Ring – closed, nonintersecting path – simple poly.
  - Disjointed Rings – multiple polygons define feature
  - Nested Rings – “island” or “atoll” polygons
Shapefile Topology

- Shapefiles don’t store information about adjacency
- Topology is generated on the fly – vertices stored in systematic fashion to deal with containment and adjacency
- **Planar enforcement can be broken by editing – not required in structure of shapefile**
- But... tools available to maintain planar enforcement when digitizing in heads-up mode

Geodatabase model

- Stores geographic coordinates as one of many attribute in a relational database table; no separation between aspatial and spatial data, as in earlier models
- Uses **MS Access** for “Personal Geodatabase” (single user)
- Uses Oracle, DB2 or other commercial relational databases for “Enterprise GIS” (many simultaneous users).

Geodatabase Model

- Data structure capable of storing objects with behaviors and relationships, not merely graphical shapes with topology and attributes
- All spatial and attribute data for a feature are stored in a row of a single table
- A Geodatabase is a top-level container for feature classes, coverages, shapefiles, rasters, et al. (more later) – ALL DATA CAN BE IN ONE CONTAINER AND ARE THUS PORTABLE
Feature classes in Geodatabase include:

- Points, Multipoints (groups of points)
- Lines
- Polygons

  Plus ....
  - Network Junctions (special Nodes)
  - Network Edges
    - For geometric networks
    - Plus other classes
  - Relationship classes
  - Object Classes – tabular data without geography

For geometric networks

Object Class

- A collection of nonspatial objects that share the same attributes and are stored in a table (i.e. a simple table)

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<tr>
<td>125</td>
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ArcGIS Geodatabase

Geodatabase Feature Datasets

- Set of Feature Classes, some with topologies, that share the same spatial reference
- All feature classes with topologies must be stored within a Feature Dataset
- Analogous to coverage

Object Class

Slide courtesy of D. Maidment
Relationship

- A relationship is an association or link between two objects in a database.
- A relationship can exist between spatial objects (features in feature classes), non-spatial objects (objects in object classes), or between spatial and non-spatial objects.

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Relationship class

E.g. relationship between spatial and non-spatial objects

Paper Map ➔ Files Of Coordinates

- How are they organized?
  - Data Models, Topology
- How are they stored?
  - Data Organization
- How are coordinates captured?
  - Data Entry, Encoding

Digitizing is:

- Conversion of spatial data to digital form
  - Lines, points or polygons are traced to record coordinates of their locations
- Term conventionally used to denote the process of creating VECTOR data
  - Scanning produces raster data ("bit maps")
  - But software exists to convert raster to vector so can digitize ("vectorize") scanned images
Digitizing is accomplished via:

- Digitizing table or tablet
  - "heads-down" digitizing
  - Large digitizing table
- A mouse, on screen
  - "heads-up" digitizing
  - Aerial photos, other raster or vector sources as base to digitize from
- Software that converts raster to vector
  - Vectorization – batch or interactive modes, e.g. ArcScan extension

Digitizing with a tablet involves:

- Digitize 3 reference points – define position of map w.r.t. digitizing table
- Establishing 4 or more control points - distinctive features at known locations that can be used to register the map to ground coordinates (e.g. UTM, lat./lon.) = "georeferencing"
- Separating features as point, line or polygon and tracing them to separate files (themes)
- (Heads-up digitizing starts with georeferencing)

Digitizing table

Digitizing strategies governed by:

- Will data be used for queries and analysis or just visual display?
  - i.e. Topology important or not?
  - "True" G.I.S. functionality or not?
- What are accuracy requirements and how much generalization is permitted?
Spaghetti vs. Topologic models

- Spaghetti: Points, lines, polygons and their attributes stored in tables
- Topological:
  - Same, but with corresponding tables of information about what’s adjacent or what’s within what

“Building Topology”

- Clean: Edit to ensure planar enforcement
  - Remove sliver polygons & gaps between polygons
  - Correct overshoots, undershoots, leaky polygons
- Build: Add topological attributes to spaghetti
  - Manual
  - Automatic
- Digitizing with topology performed in ArcInfo or with tools in ArcToolbox, ArcMap and ArcCatalog
- Changes to polygons or lines affect topological attributes – Strict rules for editing coverages in ArcMap (topology tools available)

Heads-up digitizing

- Decide whether new file will have planar enforcement
- Create new point, line or polygon feature class(es) in ArcCatalog
- Edit feature class(es) to add features and attributes
- Stop editing
- Save edits as part of new feature class