ESRI* Object Models; Data Capture

Feature Class (spatial table)

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<thead>
<tr>
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</table>

Object Class (nonspatial table)

* Environmental Systems Research Institute
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

ESRI = Environmental Systems Research Institute, Inc.
### Some ESRI History...

<table>
<thead>
<tr>
<th></th>
<th>Arc/Info</th>
<th>ArcView</th>
<th>ArcGIS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Date</strong></td>
<td>1980-1999</td>
<td>1993-1999</td>
<td>2000 - present</td>
</tr>
<tr>
<td><strong>Versions</strong></td>
<td>1–7</td>
<td>1–3.2</td>
<td>8.0 – 10.2</td>
</tr>
<tr>
<td><strong>Data Model</strong></td>
<td>Coverage</td>
<td>Shapefile</td>
<td>Geodatabase</td>
</tr>
<tr>
<td><strong>O.S.</strong></td>
<td>Unix, PC DOS</td>
<td>Windows</td>
<td>Windows</td>
</tr>
<tr>
<td><strong>Scripting</strong></td>
<td>Arc Macro Language (AML)</td>
<td>Avenue Scripting</td>
<td>Vis. Basic for Appl. (VBA), Python</td>
</tr>
<tr>
<td><strong>Database Software</strong></td>
<td>Proprietary; Arc Tables</td>
<td>DBase</td>
<td>M.S. Access; ArcSDE for Oracle, etc.</td>
</tr>
</tbody>
</table>
ArcGIS Licensing Levels

- **ArcView** – Make maps, do queries, some spatial analysis, some editing (shapefiles, personal geodatabases) – included with GTK ArcGIS Desktop

- **ArcEditor** – plus edit multi-user geodatabases; more tools in toolbox

- **ArcInfo** – full functionality; comes with ArcInfo Workstation (i.e. “legacy” ArcInfo v. 7). *UT D.G.S. licenses*
## ArcGIS Extensions

<table>
<thead>
<tr>
<th>ArcGIS Spatial Analyst</th>
<th>ArcGIS 3D Analyst</th>
<th>Geostatistical Analyst</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ArcView, ArcEditor, and ArcInfo</strong></td>
<td><strong>ArcInfo only</strong></td>
<td><strong>ArcInfo only</strong></td>
</tr>
<tr>
<td>• Advanced raster modeling</td>
<td>• ArcScene™—real-time interactive three-dimensional scenes</td>
<td>• Advanced kriging and surface modeling</td>
</tr>
<tr>
<td>• ARC GRID calculator with ARC GRID algebra</td>
<td>• Scene views in ArcCatalog</td>
<td>• Exploratory spatial data analysis tools</td>
</tr>
<tr>
<td>• VBA for raster analysis</td>
<td>• Three-dimensional modeling tools</td>
<td>• Probability, threshold, and error mapping</td>
</tr>
<tr>
<td></td>
<td>• ARC TIN™ tools</td>
<td></td>
</tr>
</tbody>
</table>
ESRI Data Models

- **Topologic:**
  - ArcInfo - Coverage
  - ArcInfo “.E00” – export format for coverage
  - ArcGIS - Geodatabase

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

Spatial Data

- 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

Aspatial Data

Geographic coordinates and attributes are stored in separate but linked files

Slide courtesy of D. Maidment
Data Organization

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

- **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

As in previous lecture
Folder/File Organization

Coverage

- Texas
  - Geology
    - aat.adf
    - arc.adf
    - pat.adf
    - Etc., Etc., Etc.
  - Info
    - arc.dat
    - arc.nit
    - Etc., Etc., Etc.

.Shapefile

- Texas
  - Geology.shp
  - Geology.shx
  - Geology.dbf
  - Geology.prj

.E00

- Texas

> One feature shape (as points OR lines OR polygons) per file = “SHAPEFILE”

> Many related features (as points AND lines AND polygons) per file = “COVERAGE”
Data Organization: Coverage in Windows Explorer and ArcCatalog

- ArcCatalog: Workspace>Coverage>Feature Class

Windows Explorer

Arc Catalog

Feature Classes

 prov4bedrk

Select an item to view its description.

See also:
My Documents
My Network Places
My Computer
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)
Coverages 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).

Slide courtesy of D. Maidment
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
Geodatabases in ArcCatalog/Windows Explorer

- Geodatabase/Feature Dataset/Feature Class

ArcCatalog

Feature Dataset

Feature Classes

Windows Explorer
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
ArcGIS Geodatabase

- Workspace
- Geodatabase
- Feature Dataset
- Feature Class
- Geometric Network
- Relationship Class
- Object Class

<table>
<thead>
<tr>
<th>OBJECTID*</th>
<th>CrossSectionID*</th>
<th>CrossSectionM</th>
<th>Elevation</th>
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<tbody>
<tr>
<td>3931</td>
<td>Colorado/L.bj Middle 66</td>
<td>3464</td>
<td>801</td>
</tr>
<tr>
<td>3932</td>
<td>Colorado/L.bj Middle 66</td>
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<td>3933</td>
<td>Colorado/L.bj Middle 66</td>
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<td>3934</td>
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<td>3511</td>
<td>739</td>
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<tr>
<td>3935</td>
<td>Colorado/L.bj Middle 66</td>
<td>3527</td>
<td>739</td>
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Slide courtesy of D. Maidment
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

- 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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Object Class (nonspatial table)
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.
Relationship class

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

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Feature Class (spatial table)

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<tr>
<th>FID</th>
<th>Shape*</th>
<th>Id</th>
<th>Number</th>
<th>NAD27 East</th>
<th>NAD27 North</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Point</td>
<td>0</td>
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<td>4630921</td>
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2/1/2018
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 table

- Map
- Cursor (Puck)
- Control Point
- Fixed Digitizing Axes
- $x_0$
- $y_0$
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 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