ESRI* Object Models; Data Capture

Feature Class (spatial table)

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

 PRODUCTS (Licensing Levels)

ArcView

ArcEditor

ArcInfo

 DATA SOURCES

Files

Databases

ArcIMS Services
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>
<th>ArcInfo only</th>
</tr>
</thead>
<tbody>
<tr>
<td>ArcView, ArcEditor, and ArcInfo</td>
<td>ArcScene™—real-time interactive three-dimensional scenes</td>
<td>Advanced kriging and surface modeling</td>
<td>ARC GRID program in ArcInfo Workstation</td>
</tr>
<tr>
<td>Advanced raster modeling</td>
<td>• Scene views in ArcCatalog</td>
<td>Exploratory spatial data analysis tools</td>
<td>ARC GRID commands in Arc program</td>
</tr>
<tr>
<td>ARC GRID calculator with ARC GRID algebra</td>
<td>• Three-dimensional modeling tools</td>
<td>Probability, threshold, and error mapping</td>
<td>ARC TIN™ commands in Arc program</td>
</tr>
<tr>
<td>VBA for raster analysis</td>
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<td></td>
<td>Surfascene command</td>
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</table>
ESRI Data Models

Topologic:
- ArcInfo - Coverage
- ArcInfo “.EOO” – 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

Arc

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

Info

Geographic coordinates and attributes are stored in separate but linked files

Aspatial Data

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:
  Filesystem structure

Arc Catalog

Feature Classes

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

Sample location (points) Feature Class
ArcInfo Coverage

An integrated, homogeneous set of feature classes (pts., lines, polygons) stored together:
- 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

Window Explorer

ArcCatalog
Shapefile feature class types:

- **Point, Multipoint**
  - Point
  - Multipoint

- **Polyline (line with several paths)**
  - Polyline

- **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

In ArcCatalog, you can see the structure of a geodatabase with folders for different feature datasets. Each feature dataset contains feature classes. In Windows Explorer, the geodatabase and its contents can be viewed similarly, with directories for feature datasets and classes.
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

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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Paper Map $\rightarrow$ 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**

Y-axis

X-axis

$\mathbf{x}_o$

$\mathbf{y}_o$
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