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></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</strong></td>
<td>Proprietary; Arc Tables</td>
<td>DBase</td>
<td>M.S. Access; ArcSDE for Oracle, etc.</td>
</tr>
<tr>
<td><strong>Software</strong></td>
<td></td>
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</tr>
</tbody>
</table>
ArcGIS Desktop Levels

PRODUCTS (Licensing Levels)

ArcView

ArcEditor

ArclInfo

DATA SOURCES

Files

Databases

ArclMS 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). \textit{UT D.G.S. licenses}
## ArcGIS Extensions

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

- **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

- 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**
  - Feature Classes

- **Arc Catalog**
  - prov4bedrk
  - Extracted_Maps
  - My_shapefiles
  - info
  - My Documents
  - My Network Places
  - My Computer

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

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**
- **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 attributes 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

Windows Explorer

ArcCatalog

Feature Dataset

Feature Classes

ArcCatalog
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 - 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 table once available in Rm. 6.202
- 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**

![Diagram showing digitizing table components](image)
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.)
- 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
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