Managing Data for Retrieval, Update, & Calculation

Databases

GIS Data Recap

Two data types:
- Spatial – Where things are, in \( (x, y, \lambda, \phi) \)
- Stored in coordinate files & topology tables
  - Vector (Object) Model
  - Raster (Field) Model
- Aspatial - What things are
  - Stored in tables of attributes

GIS = Lots and Lots of Tabular Data

- How will it be managed?
  - Data Model Considerations
  - Analysis Considerations
  - Data Entry Considerations
  - Security
  - Efficiency

HOW?

- Goals:
  - Maximize flexibility for sorting, reordering, subsetting, searching
  - Efficient storage; eliminate redundancy
  - Secure entry and retrieval mechanisms
  - Rapid retrieval

- Solution:
  - Database Management System (DBMS)
Database display in ArcMap

- Displayed in tables with rows of records (tuples) and columns of fields (attributes)

![Database display in ArcMap](image)

**Accuracy**

- Data entry can be accomplished via forms that require:
  - Data definitions – #s of attributes, the types and lengths or numerical ranges of each attribute, and how much editing will be permitted.
  - Data Dictionary - catalog of attributes with their permitted values and ranges ("Domains").
  - Validation Rules - ensure data integrity.

**Data Definition: Field “Types”**

- Field type - Q: how much space does a database need to reserve for each field?
- A: no more than 10 characters

**Fields are “defined” by:**

- Name – attribute (column heading)
- Field Type – number (long, short, float, double), text ("string"), or date
- Length – no. of characters in text
- Precision – no. of digits used to store numbers
- Scale – no. of digits to right of decimal point

![Field Definitions](image)
Spatial Databases

Fields Types in ArcGIS

- Short Integer – 1 to 4 digits (no decimal)
- Long Integer = 5 to 9 digits (no decimal)
- Float = 1 – 8 digits, decimal (short real)
- Double = 6 – 19 digits, decimal (long real)
- Text = 1 – 255 characters
- Date = 8 character
- Blob = binary large object

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Storage</th>
<th>Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Integer</td>
<td>2 bytes</td>
<td>+/-32,768</td>
<td>Used for coding, e.g. lulc, veg. types, T/F</td>
</tr>
<tr>
<td>Long Integer</td>
<td>4 bytes</td>
<td>+/-2.14 billion</td>
<td>Large whole numbers, e.g. populations</td>
</tr>
<tr>
<td>Float</td>
<td>4 bytes</td>
<td>+/-3.4 x E38</td>
<td>Single-precision, up to 6 places past the decimal. Up to 6 total numbers.</td>
</tr>
<tr>
<td>Double</td>
<td>8 bytes</td>
<td>~+/−1.8 x E308</td>
<td>Double-precision; 15 places past decimal, 6-19 total numbers.</td>
</tr>
</tbody>
</table>

Field Properties

- Precision = number of digits stored in a field. Precision 7 for double, 16 for float
- Scale = no. of decimal places in double and float
- E.g. 3500426.21 should be stored as double, precision >9, scale > 2

Numeric Field Properties

- Short and Long integers fields:
  - Precision = 4
  - 8,400
- Float and Double data fields:
  - Precision = 9
  - 8,400.08347
  - Scale = 5
File Size Comparison, Text Fields

<table>
<thead>
<tr>
<th>Text Field length</th>
<th>100 records</th>
<th>1000 records</th>
<th>10,000 records</th>
<th>100,000 records</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.2 Kb</td>
<td>1.95 Kb</td>
<td>19.53 Kb</td>
<td>195.3 Kb</td>
</tr>
<tr>
<td>50 (default)</td>
<td>4.88 Kb</td>
<td>48.83 Kb</td>
<td>488.3 Kb</td>
<td>4.88 Mb</td>
</tr>
</tbody>
</table>

Accuracy

- Data entry can be accomplished via forms that require:
  - Data definitions – #s of attributes, the types and lengths or numerical ranges of each attribute, and how much editing will be permitted.
  - Data Dictionary - catalog of attributes with their permitted values and ranges (“Domains”).
  - Validation Rules - ensure data integrity.

Data Dictionary: Domains

- Permitted attribute values or range of values for a field:
  - E.g. dip of bedding: permissible range from 0-90°
  - E.g. type of geologic contact: permissibly covered, inferred, exposed
  - E.g. rock type: permissibly sandstone, shale, limestone

Domains in a Geodatabase
A DBMS provides:

- **Accuracy** - reduce errors during entry by use of established rules, templates
  - Efficiency - rapid access & retrieval, no redundancy
  - Flexibility - robust structure for query – e.g. What is where?
  - Security – access and use can’t corrupt data
  - Easy updating

Efficiency (+ Flexibility)

- Relies on database structure (data model):
  - Hierarchical
  - Network
  - Relational
  - Object-oriented

GIS attribute data models

- **Hierarchical** – pre-1980
- **Relational** – 1980’s, 1990’s; still dominant today
- **Object-oriented** – late ‘90’s; newest, implemented by some GISs – still undergoing R&D

Hierarchical Structure

- File address for storage and retrieval is a linear path, e.g. 
  C:\ESRI\ESRIDATA\CANADA\cities.shp
Hierarchical Structure

University
- ORUs
- Colleges
- Administration
- Departments
- Allied Units
- Graduate Students
- Undergraduate Students

Hierarchical - Limitations

1. Linear structure can’t deal with multiple "memberships"
   - E.g. a single well might be stored many times in different databases for taxes, production, drilling history, water quality, etc.
   - INEFFICIENT
   - Can’t assemble all this data for query in a hierarchical database

2. Can’t deal with exceptions to linear scheme – entities may not belong to next higher class but could instead contain it.
   - E.g. Structure Oil Well Database by:
     - State
     - County
     - Oil Field
     - Well
     - Pay zone
   - What do we do with a oil field that spans several counties with wells that produces from more than one pay zone?
   - i.e. No "one-to-many" relationships

Relational Database Advantages

- Data stored in separate tables
- Easy update, editing, searching without affecting or using all data
- Flexibility
  - Using "key" fields, can extract and assemble records and attributes to form new tables
  - Subsets of database can be queried by standard means - SQL
Relational Database Structure

- Consists of “relations” (tables) with multiple attributes (columns, fields) per record
- Every record (row) has a unique identifier (marker or key attribute)
- Key is the glue between files that can be used to extract and/or assemble records and attributes

Properties of Relations

- Each row has to be unique; no row-to-row dependency
- Row order irrelevant
- Column order irrelevant
- All attribute values must be stored in separate rows (“first normal form”)

Relational Database Structure

- “Key” Field = ID

Parts of a Relation

- Primary Key
- Record or tuple
- Attribute or field
Spatial Databases

One-to-One Table “Join”

- One record from **source table** (production) is joined to one record of **destination table** (drilling record) to create a “View” – virtual combination.

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Spudded</th>
<th>Completed</th>
<th>Production (barrels/day, cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>Exxon #1</td>
<td>2/4/96</td>
<td>6/3/96</td>
<td>40</td>
</tr>
<tr>
<td>43</td>
<td>Shell #5</td>
<td>3/14/97</td>
<td>6/12/96</td>
<td>43</td>
</tr>
</tbody>
</table>

- **Oil**  | **Gas**  | **Water** |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>53</td>
<td>1200</td>
</tr>
<tr>
<td>43</td>
<td>108</td>
<td>2500</td>
</tr>
</tbody>
</table>

Result of One-to-One Table “Join”

- Joined Production and Drilling Record tables:

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Spudded</th>
<th>Completed</th>
<th>Oil</th>
<th>Gas</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>Exxon #1</td>
<td>2/4/96</td>
<td>6/3/96</td>
<td>53</td>
<td>1200</td>
<td>5</td>
</tr>
<tr>
<td>43</td>
<td>Shell #5</td>
<td>3/14/97</td>
<td>6/12/96</td>
<td>108</td>
<td>2500</td>
<td>15</td>
</tr>
</tbody>
</table>

- View can’t be edited – destination table can be edited.

One-to-Many Join

- One record from **source table** (production) joined to many records of **destination table**

<table>
<thead>
<tr>
<th>ID</th>
<th>Well Name</th>
<th>Spudded</th>
<th>Completed</th>
<th>Field_ID</th>
<th>Name</th>
<th>Discovered</th>
<th>Total_Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>Exxon #1</td>
<td>2/4/96</td>
<td>6/3/96</td>
<td>2</td>
<td>Katy</td>
<td>2/3/48</td>
<td>85640</td>
</tr>
<tr>
<td>43</td>
<td>Shell #5</td>
<td>3/14/95</td>
<td>6/12/96</td>
<td>2</td>
<td>Katy</td>
<td>2/3/48</td>
<td>85640</td>
</tr>
</tbody>
</table>

Table of Wells in Katy Field

- Note that “Discovered” and “Total_Oil” fields in joined table pertain to Katy Field, not to individual wells! This could be a problem...

<table>
<thead>
<tr>
<th>Field_ID</th>
<th>Name</th>
<th>Discovered</th>
<th>Total_Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Longview</td>
<td>2/10/56</td>
<td>13000564</td>
</tr>
<tr>
<td>2</td>
<td>Katy</td>
<td>2/3/48</td>
<td>85640</td>
</tr>
<tr>
<td>3</td>
<td>Anahuac</td>
<td>4/11/73</td>
<td>35878889</td>
</tr>
</tbody>
</table>
Many-to-Many Join example – USGS DLGs

- Join “lookup table” with feature codes tables to obtain feature descriptions
- Feature descriptions stored once, used many times
- Primary key is feature code

Digital Line Graph Example

- Lookup Table
- Key
- Hydrography feature attributes

Result of Many-to-Many Join

- Symbolize on joined field (FEAT_DESC)

A DBMS provides:

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- Efficiency - rapid access & retrieval, no redundancy
  - Flexibility - robust structure for query – e.g. What is where?
  - Security - access and use can’t corrupt data
  - Easy updating
Flexibility

- Using primary key(s), can extract and assemble records and attributes to form new tables, as discussed
- Subsets of database can be queried by standard means - SQL

ArcMap Query Builder

- E.g. Find all cities in Louisiana where 1990 population exceeded 72,033

Relational DBMSs Permit:

- File updating
- Data retrieval via query using a standard language (SQL)
- Sorting (reordering) by field values
- Calculations and field statistics
- Report generation
- Multi-user access

Reordering In ArcMap

1. Order selected records by sorting:
   - ascending or descending field values
2. Sort records by selected attributes

Unsorted

Sorted by “Azimuth”
Field Statistics In ArcMap

- Get stats. & graphs on selected attributes

Statistics for “Azimuth”

Histogram for “Dip”

GIS’ are Spatial Databases

- Coverage and Shapefile models
  - Spatial information stored in spatial attribute files, attributes in relational database table
  - Feature ID is key
  - Spatial information can't participate in relational database advantages

- Geodatabase model
  - All information, spatial and aspatial, are stored together in a relational database