Raster Data and ArcGIS Spatial Analyst

- Raster Concepts
- Why use Raster Data?
- ArcGIS Spatial Analyst
Cartographic Abstraction

• **Tessellations**: ways of dividing up geographic space

• Begin by **conceptualizing and filtering** geographic reality
  – Involves a **selective** process
    • What is **important** (for the application)
    • What is to be **included**
Cartographic Abstraction
Geography as Raster

• A raster is a matrix of equal-sized cells
• These are organized in rows and columns
• Each cell stores a number/value
**Raster Data Model**

- The raster data model represents the Earth’s surface as an array of two-dimensional grid cells, with each cell having an associated value:

```
  1  2  3  5  8
  4  6  8  3  9
  3  5  3  3  1
  7  5  4  3  9
  2  2  4  5  2
```

- **Cell (x,y)**: Cell value
- **Cell size = resolution**
Raster Data Model

• Each grid cell in a raster data layer is one **unit** (the minimum amount of information in the raster data model)

• Every cell has a **value**, even if it is a special value to indicate that there is “no data” or that data is “missing” at that location

• The values are numbers, either:
  – **absolute values OR**
  – **codes** representing an **attribute**
Cells - Absolute Values

• In this instance, the value of the cell is actually the value of the phenomenon of interest, e.g. elevation data (whether floating point or integer):
Cells - Coded Values

• Here, the values stored in each cell are used as substitutes for some nominal or categorical data, e.g. land cover classes:

<table>
<thead>
<tr>
<th>ID</th>
<th>Land Cover Type</th>
<th>Ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grass</td>
<td>Smith</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Water</td>
<td>Smith</td>
</tr>
<tr>
<td>13</td>
<td>Sand</td>
<td>Smith</td>
</tr>
</tbody>
</table>
Cells – Coded Values

• The coded values can then link to one (or more) attribute tables that associate the cell values with various themes or attributes:
Raster coordinate systems

- Image cell origin
- Cell (0,0)
- Column 500 m
- Row 500 m
- Cell (0,3)
- Grid origin
- Coordinate system origin
- Transformation (530, 684)
- Matrix/Cartesian origin
- Cell (8,9)
- Map projection origin (0,0)
Raster registration and georeferencing

- Raster data should be registered to real-world coordinates (a projection)

- If all rasters are registered to a common projection, they are registered to one another
Raster Resolution

- **Cell size**: smaller cells $\rightarrow$ higher resolution
  - Impacts accuracy, processing speed, storage
Raster generalization

- **Accuracy**
  - True polygon area = 679,707 sq. meter
    - Larger cells = lower resolution

- **Implications**
  - Storage space
  - Processing speed
Raster Format Essentials

• All raster formats are **basically the same**:
  – Cells in a **matrix** of rows and columns
  – Contents: Data or picture?

• **Raster data**
  – Elevation, Landuse, Population
  – Analysis (Slope)
  – Mapping (Thematic, Derivative products)

• **Raster pictures**
  – Scanned maps
  – Satellite images
  – Good for mapping (as backgrounds)
  – Bad for analysis
Why Use Raster?

- **Easier** than vector in **many** analyses
- **Fast overlays** with complex data
- More analysis **options**
- Allows:
  - Location view of data
  - Surface analysis (visibility, etc.)
  - Distance analysis (weighted, decay distances, etc.)
Discrete and Continuous Data

• **Discrete data**
  – Models **bounded** data
    • Land use, zoning, and so on
  – Stored as **integer** values

• **Continuous data**
  – Models **surfaces**
    • Elevation, distance
  – Stored as **floating-point or integer values**
Quantizing Geographic Space

- **Converts both** discrete and continuous data into discrete packets
  - Less exact locationally than vector
  - Stores all entities in *uniform* fashion
  - As amount of ground represented by grid cells increases (decreased resolution) the locational accuracy decreases
Entities to Raster

• Once **objects (entities)** are **selected**:  
  • **Divide into quanta**  
    – i.e. packets of information  
    – Requires **deciding**…  
      • Minimum mapping unit  
      • Grid cell size  
      • Tessellation type
Grid Cells

- **Represent** known or perceived **entities**
  - Plus their **descriptive information** (attributes)

- **Typical entities:**
  - **Points** (single grid cell)
  - **Lines** (strings of grid cells)
  - **Polygons** (areas or groups of grid cells)
1 point = 1 cell

What problem do we have here? How can we solve it?
Raster Data Model - Lines

A line = a series of connected cells that portray length

Is there a problem with this representation?
Area = a group of connected cells that portray a shape

What problems could we have with this representation?
Raster and Vector Data Model Comparison

Real World Features | Raster | Vector

"A raster model tells what occurs everywhere, while a vector model tells where every thing occurs"
Features as raster

- Vector
  - Points
- Raster
  - Lines
  - Polygons

- Raster loses feature uniqueness (a line is a collection of cells, not one feature)
ArcMap Raster Tools

- **Display in ArcMap**
  - **Both** raster and vector
  - Order of display
  - Transparency

- **Raster data can be:**
  - ArcSDE rasters
  - GRIDs
  - Images
ArcGIS Spatial Analyst

• Provides a rich **modeling environment**
  – Derive **new information**
  – Identify **spatial relationships**
  – Find **suitable** locations
  – Calculate (travel) **cost**
  – Can be used with all **cell-based** GIS data
ArcGIS Spatial Analyst in ArcMap

 Toolbar in ArcMap

![Image of ArcGIS Spatial Analyst toolbar]

David Tenenbaum – EEOS 465 / 627 – UMass Boston
The ArcGIS Spatial Analyst user interface

Toolbar
- Spatial Analyst
- Layer: prarieutm

Create contours
- Straight Line...
- Allocation...
- Cost Weighted...
- Shortest Path...

Histogram
- Inverse Distance Weighted...
- Spline...
- Kriging...

Distance functions
- Contour...
- Slope...
- Aspect...
- Hillshade...
- Viewshed...

Generate surfaces from sample data points
- Features to Raster...
- Raster to Features...

Surface functions
- Convert data

Set analysis environment

Functions:
- Local
- Focal
- Zonal

Map Algebra
- Distance
- Density...
- Interpolate to Raster
- Surface Analysis
- Cell Statistics...
- Neighborhood Statistics...
- Zonal Statistics...
- Reclassify...
- Raster Calculator...
- Convert
- Options...
Map Algebra and the Raster Calculator

- Map Algebra
  - Build expressions
  - Operators
  - Functions
  - Rules and syntax

- Use the Raster Calculator to enter expressions
  - For features not on the user interface or advanced analysis

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>In UI</th>
<th>In RC only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operators</td>
<td>29</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Functions</td>
<td>168</td>
<td>51</td>
<td>117</td>
</tr>
<tr>
<td>Totals</td>
<td>197</td>
<td>66</td>
<td>131</td>
</tr>
</tbody>
</table>
ArcGIS Spatial Analyst is flexible

- Activate the extension
- Add the toolbar

- Analyze all supported rasters
Seven Interfaces for Spatial Analyst
Cell value storage

- Long Integer
  - Range of legal values

- Single precision floating point
  - Range of legal values

- NoData
  - What it is
  - What its value is

```
Integer
No Data 1 1 1
No Data 1 2 2
1 1 2 2
```

```
Floating point
1.112 3.822 3.755 3.432
0.257 1.829 2.867 2.993
0.000 0.923 0.712 0.448
0.000 0.181 No Data No Data
```

```
1 Forest
2 Water
```
Raster Representation in ASCII data format

```plaintext
cols 221
nrows 227
xllcorner 6822435.796579
yllcorner 1827799.620088
cellsze 144.903332
NODATA_value -9999
```

```
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
-9999 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 6 6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6
```

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Extending the Raster Model

• An extension of the raster model allows it to fit into the MAP model (Dana Tomlin’s approach, analogous to that in ArcGIS):
  – **Themes** are the primary items being addressed / used / manipulated
  – Extending the raster model allows **rasters to be themes** as well, then by…
    • Adding / linking **tabular data** to the spatial representation
    • Allowing **multiple attributes** for each theme in the raster domain
Grid attributes

- Integer grids may have an attribute table
  - One record per zone (unique values)
  - Always have VALUE, COUNT fields
- You may add fields
- Relate to other tables with ArcMap
- Floating-point grids
  - No attribute table

<table>
<thead>
<tr>
<th>VALUE</th>
<th>COUNT</th>
<th>TYPE</th>
<th>CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>MAPLE</td>
<td>400</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>OAK</td>
<td>500</td>
</tr>
</tbody>
</table>

Forest

Tree_data

<table>
<thead>
<tr>
<th>VALUE</th>
<th>DENSITY</th>
<th>BUG_DAMAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>65</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>74</td>
<td>14</td>
</tr>
</tbody>
</table>

User-defined

Relate
Extending the Raster Model, Cont.

• What are the **advantages** over simple raster?
  
  – Increased **attribute data** for each theme
    • Less storage space
    • More possibilities
  
  – Puts this **additional data** at users’ fingertips
    • As modeling is performed, these **attributes are carried** with each theme
    • Also carried with **newly created themes**
User attributes in expressions

You may use numeric VAT fields in expressions

Reference with [Layer].field notation

<table>
<thead>
<tr>
<th>Value</th>
<th>Count</th>
<th>Desc</th>
<th>Suit</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>2450</td>
<td>Grass</td>
<td>1</td>
</tr>
<tr>
<td>201</td>
<td>65780</td>
<td>Mixed</td>
<td>3</td>
</tr>
<tr>
<td>301</td>
<td>32187</td>
<td>Pine</td>
<td>2</td>
</tr>
<tr>
<td>401</td>
<td>5433</td>
<td>Oak</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value</th>
<th>Count</th>
<th>Desc</th>
<th>Suit</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>2450</td>
<td>Sand</td>
<td>2</td>
</tr>
<tr>
<td>46</td>
<td>65780</td>
<td>Loam</td>
<td>1</td>
</tr>
<tr>
<td>87</td>
<td>32187</td>
<td>Clay</td>
<td>6</td>
</tr>
<tr>
<td>99</td>
<td>5433</td>
<td>Rock</td>
<td>9</td>
</tr>
</tbody>
</table>

[Vegetation].Suit + [Soil].Suit

[Layer] alone is assumed to be [Layer].Value

You may join tables to grids VAT file

Use joined fields for symbology, selection

Cannot use in Map Algebra expressions
Quadtree Data Model

• So far, all the data models we have seen make use of a uniform tessellation
  – Wastes space

• But most compact tessellations are not appropriate for modeling

• Quadtrees (based on AI research)
  – Variable size tessellation
  – Allows modeling
The quadtree method **recursively subdivides** the cells of a raster grid into quads (quarters) until each **quad** can be represented by a **unique cell value**:

The number of subdivisions depends on the **complexity** of features and stores **more detail** in areas of greater complexity.
Exercise 2: Raster Concepts

• **Explore** raster concepts
• **Set** the raster **analysis environment**
  – Analysis extent, cell size, mask
• **Clip** a raster dataset
  – With the analysis extent (rectangular shape)
  – With the mask (irregular shape)
• **Snap the extent** to a specific raster
Raster Formats

• The data format is **how cells are stored** in a raster
• ArcGIS supports **dozens** of raster formats
  – Various image formats (SID, IMG, TIF, etc.)
  – ESRI GRID Format
  – ESRI ArcSDE raster
  – ESRI raster dataset
  – ESRI raster catalog
  – All may be managed in ArcCatalog
  – All may be used with the Spatial Analyst
ESRI GRID Format

- **Native format** for Spatial Analyst
  - Default output from most tools
  - A folder containing multiple files
  - Have associated INFO tables
    (must manage grids with ArcCatalog **only**)
- **Two types**: Floating point & Integer
- **Integer grids** may have user-defined attribute fields
The grid data model

- Native data structure for ArcGIS Spatial Analyst
  - Analysis creates output grids
  - Cells stores data values (not colors like images)
  - May have an attribute table, participate in relationships

- Manage with ArcCatalog

```
MyProject
  ├── MyData
  │    ├── info
  │    │    └── Grid attributes
  │    └── soils
  │         └── Grid data sets
  └── Workspace directory
      ├── slope
      └── forest
```
Resampling

- Automatically applied when combining rasters

Map Algebra operation

Input

Output

Different cell size

Output cell center identifies the input value
Resampling methods

- Nearest neighbor
- Bilinear interpolation
- Cubic convolution
The analysis environment

- Controls how the output raster is created

- Set in the ArcGIS Spatial Analyst > Options dialog
Setting the projection

- Rasters may be projected during analysis operations
- Choose an output projection:
  - Same as first input layer
  - Same as data frame
- You may change the data frame projection
Setting the Output Cell Size

• When combining rasters with different cell sizes; output another size:
  – Maximum of Inputs (default)
  – Minimum of Inputs
  – Same as Layer
  – As Specified Below
Setting the cell size

- As specified below
- Same as a specific layer
- Maximum of inputs
- Minimum of inputs
Setting the analysis extent

As specified below

Intersection of inputs

Same as display

Union of inputs

Same as a specific layer
Snapping the extent

- Snaps the specified extent to cells in a raster layer
- Ensures that output cells align with the snap layer

Without snapping

With snapping
Setting the Output Extent

• This **controls the width and height** of the resulting output raster:
  – Combine rasters with **different extents**; output another extent

• Output **options**:
  – Union of Inputs (default)
  – Intersection of Inputs
  – Same as Layer
  – Same As Display
  – As Specified Below
Setting the Analysis Mask

• Vector mask
  – Only **cells covered by features** are output (others set to NoData)
  – Create a feature mask with **selection** and export

• Raster mask
  – Only **cells covered by valued cells** are output (others set to NoData)
  – Create a raster mask with any **number of** Spatial Analyst techniques

• Defines **areas where analysis is performed**
  – Useful for clipping to **irregular shapes**
Setting the analysis mask

- Define areas where analysis is performed

- NoData in mask = NoData in output

- Several ways to create a mask
Exercise 2: Raster Concepts

• **Explore** raster concepts
• **Set** the raster *analysis environment*
  – Analysis extent, cell size, mask
• **Clip** a raster dataset
  – With the analysis extent (rectangular shape)
  – With the mask (irregular shape)
• **Snap the extent** to a specific raster
Resources for Further Study

• Online Help
• Documentation
  – Using ArcGIS Spatial Analyst by Jill McCoy and Kevin Johnston
• Knowledge Base
• Virtual Campus courses
  – http://campus.esri.com
• ArcObjects Online
  – http://arconline.esri.com/arcobjectsonline
• Online Support Center
  – http://support.esri.com
Next Topic:

Raster Representations and Calculations