Python – Raster Analysis

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Outline

- Managing rasters and performing analysis with Map Algebra
- How to access the analysis capability
  - Demonstration
- Complex expressions and optimization
  - Demonstration
- Additional modeling capability: classes
  - Demonstration
- Full modeling control: NumPy arrays
  - Demonstration
A complex model

Emerald Ash Borer

Originated in Michigan
Infest ash trees
100% kill
Coming to Vermont
The Ash Borer model

• Movement by flight
  - 20 km per year
  - Vegetation type and ash density (suitability surface)

• Movement by hitchhiking
  - Roads
  - Camp sites
  - Mills
  - Population
  - Current location of the borer (suitability surface)

• Random movement
Typical problem just like yours: The Characteristics

- **Complex**
- **Multiple input types**
  - Need to work with rasters along with features and tables
- **Scenarios**
  - Repeat analysis by using different parameter values
- **Dynamic**
  - Time is explicit, need to run sections multiple times
- **Enhanced capabilities**
  - Need to take advantage of 3rd party Python packages
- **Reusable**
  - Repeat the workflow with the same or different set of data
- **Performance and optimization**

*Ideal for Map Algebra and Python scripting*
The Ash Borer model

- Prepare the data
- An iterative model – based on a year
- Three sub models run individually each iteration and the results are combined
  - Movement by flight (run 3 different seasons)
  - Movement by hitchhiking (run once)
  - Random movement (run once)
Raster analysis – Preparing the data

• To prepare and manage raster data
  - Displaying
  - Adding, copying, deleting, etc.
  - Mosaic, Clip, etc.
  - Raster object
  - NumPy, ApplyEnvironment, etc.

• To perform analysis
  - Spatial Analyst
  - Map Algebra
What is Map Algebra

- Simple and **powerful algebra** to execute Spatial Analyst tools, operators, and functions to perform geographic analysis
- The strength is in creating **complex expressions**
- Available through Spatial Analyst module
- Integrated in Python (all modules available)
Importing Spatial Analyst

- Module of ArcPy site package
- Like all modules must be imported
- To access the operators and tools in an algebraic format the imports are important

```python
import arcpy
from arcpy import env  # Analysis environment
from arcpy.sa import *
```
General syntax

- Map Algebra available through an algebraic format

- Simplest form: output raster is specified to the left of an equal sign and the tool and its parameters on the right

  ```python
  from arcpy.sa import *
  outRas = Slope(indem)
  ```

- Comprised of:
  - Input data
  - Tools
  - Output
  - Operators
  - Parameters
Input for analysis

• Rasters
• Features
• Numbers and text

• Objects
• Constants
• Variables

Tip: It is good practice to set the input to a variable and use the variable in the expression. Dataset names are quoted.

```
inRaster1 = "C:/Data/elevation"
outRas = Slope(inRaster1)
```
Map Algebra operators

- Symbols for *mathematical operations*

- Many operators in both Python and Spatial Analyst

  ```
  outRas = inRaster1 + inRaster2
  ```

- Creating a raster object (*Raster class constructor - casting*) indicates operator should be applied to rasters

  ```
  elevMeters = Raster("C:\data\elevation") * 0.3048
  outSlope = Slope(elevMeters)
  ```
Map Algebra tools

- All Spatial Analyst tools are available (e.g., Sin, Slope, Reclassify, etc.)

```python
outRas = Aspect(inRaster)
```

- Can use any Geoprocessing tools

Tip: Tool names are case sensitive
Tool parameters

- Defines how the tool is to be executed
- Each tool has its own unique set of parameters
- Some are required, others are optional
- Numbers, strings, and objects (classes)

\[ \text{Slope}(\text{in raster}, \{\text{output measurement}\}, \{\text{z factor}\}) \]

1. \( \text{outRas} = \text{Slope}(\text{inRaster}, \text{"DEGREE"}, 0.3048) \)
2. \( \text{outRas} = \text{Slope}(\text{inRaster}, \text{""}, 0.3048) \)
3. \( \text{outRas} = \text{Slope}(\text{inRaster}) \)

Tip: Keywords are in quotes
Map Algebra output

- Stores the results as a **Raster object**

- Object with methods and properties

- In scripting the output is **temporary**

- Associated data will be deleted if not explicitly saved
Access to Map Algebra

- **Raster Calculator**
  - Spatial Analyst tool
  - Easy to use calculator interface
  - Stand alone or in ModelBuilder

- **Python window**
  - Single expression or simple exploratory models

- **Scripting**
  - Complex models
  - Line completion and colors
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Data management and accessing the capability

Raster management tools
Raster Calculator
Python window
Model Builder
Simple expression
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Complex expressions

- Multiple operators and tools can be implemented in a single expression

- Output from one expression can be input to a subsequent expression

```python
inRaster = ExtractByAttributes(inElevation, "Value > 1000")
out = Con(IsNull(inRaster), 0, inRaster)
```
More on the raster object

- A variable with a pointer to a dataset
- Output from a Map Algebra expression or from an existing dataset
- The associated dataset is temporary (from Map Algebra expression) - has a save method
  
  ```
  outRas = Slope(inRaster)
  outRas.save("sloperaster")
  ```
- A series of properties describing the associated dataset
  - Description of raster (e.g., number of rows)
  - Description of the values (e.g., mean)
Optimization

• A series of local tools (Abs, Sin, CellStatistics, etc.) and operators can be optimized

• When entered into a single expression each tool and operator is processed on a per cell basis
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Movement by hitchhiking

- Hitchhike on cars and logging trucks
- Most likely spread around
  - Roads
  - Populated areas (towns and camp areas)
  - Commercial area (mills)
- Have a susceptibility surface
  - Vegetation types and density of ash
- Nonlinear decay
- Random points and check susceptibility
Movement by hitchhiking

Roads, campsites, mills, population, and current location (suitability)
Complex expressions
Raster object
Optimization
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Classes

- Objects that are used as parameters to tools
  - Varying number of arguments depending on the parameter choice (neighborhood type)
  - The number of entries can vary depending on situation (remap table)

- More flexible

- Query the individual arguments

```plaintext

Syntax

Net rectangle ([width], [height], [units])

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Explanation</th>
<th>Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>width</td>
<td>The width of the rectangle neighborhood. If only the width is specified, the resulting neighborhood is a square. (The default value is 3)</td>
<td>Double</td>
</tr>
<tr>
<td>height</td>
<td>The height of the rectangle neighborhood. If only the height is specified, the resulting neighborhood is a square. (The default value is 3)</td>
<td>Double</td>
</tr>
</tbody>
</table>
| units     | Defines the units of the neighborhood.  
  - CELL — The unit of measurement is in cells.  
  - MAP — The units are in map coordinates. (The default value is CELL) | String    |

Properties

<table>
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</tr>
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</table>
```
Classes - Categories

- General
  - Fuzzy
  - Horizontal Factor
  - KrigingModel
  - Neighborhood
- Time
- Vertical Factor
- Radius
- Transformation functions
- Composed of lists
  - Reclass
  - Topo
- Weighted reclass tables
General classes - Capability

- Creating
  
  ```python
  neigh = NbrCircle(4, "MAP")
  ```

- Querying
  
  ```python
  radius = neigh.radius
  ```

- Changing arguments
  
  ```python
  neigh.radius = 6
  ```
Classes composed of lists

- **Topo**
  
  ```python
  inContours = TopoContour([['contours.shp', 'spot_meter']])
  ```

- **Reclassify**
  
  ```python
  remap = RemapValue([["Brush/transitional", 0],
  ["Water", 1],["Barren land", 2]])
  ```

- **Weighted Overlay**
  
  ```python
  myWOTable = WOTable([[inRaster1, 50, "VALUE", remapsnow],
  [inRaster2, 20, "VALUE", remapland],
  [inRaster3, 30, "VALUE", remapsoil] ], [1, 9, 1])
  ```
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Movement by flight

- Fly from existing locations - 20 km per year
- Based on iterative time steps
  - Spring, summer, fall, and winter
- Time of year determines how far it can move in a time step
- Suitability surface based on vegetation type and ash density
- Iterative movement logic
  - “Is there a borer in my neighborhood”
  - “Will I accept it” – suitability surface
Movement by flight

20 km per year
Vegetation type/ash density (suitability)
Classes
Using variables
Vector integration
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  - Demonstration
NumPy Arrays

• A generic Python storage mechanism

• Create custom tool

• Access the wealth of free tools built by the scientific community
  - Clustering
  - Filtering
  - Linear algebra
  - Optimization
  - Fourier transformation
  - Morphology
NumPy Arrays

- Two tools
  - RasterToNumPyArray
  - NumPyArrayToRaster
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Random movement

- Some of the movement cannot be described deterministically
- Nonlinear decay from known locations
- Specific decay function not available in ArcGIS
- NumPy array
  - Export raster
  - Apply function
  - Import NumPy array back into a raster
- Return to ash borer model and integrate three movement sub models
Random movement

Random movement based on nonlinear decay from existing locations
Custom function
NumPy array
Summary

- When the problem becomes more complex you may need additional capability provided by Map Algebra
- **Map Algebra** powerful, flexible, easy to use, and integrated into Python
- Accessed through: Raster Calculator, Python window, ModelBuilder (through Raster Calculator), and scripting
- Raster object and classes
- Create models that can better **capture interaction** of phenomena
Additional resource

• Suitability modeling case study

• Cost distance analysis case study

• Spatial Analyst Resources
  https://www.esri.com/arcgis-blog/products/arcgis-pro/analytics/spatial-analyst-resources/

• Raster Analysis and Spatial Analyst Sessions at UC 2018
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2. Select the session you attended.
3. Scroll down to find the feedback section.
4. Complete answers and select “Submit.”