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
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
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

\[
\text{outRas} = \text{inRaster1} + \text{inRaster2}
\]

- Creating a raster object (\textbf{Raster class constructor - casting}) indicates operator should be applied to rasters

\[
\text{elevMeters} = \text{Raster("C:\data\elevation")} \times 0.3048
\]

\[
\text{outSlope} = \text{Slope(elevMeters)}
\]
Map Algebra tools

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

  \[ \text{outRas} = \text{Aspect(}\text{inRaster} \text{)} \]

- 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)

```python
Slope(in_raster, {output_measurement}, {z_factor})
```

```python
outRas = Slope(inRaster, "DEGREE", 0.3048)
outRas = Slope(inRaster, "", 0.3048)
outRas = Slope(inRaster)
```

**Tip:** Keywords are in quotes
Map Algebra output

- Stores the results as a **Raster object**
- Object with methods and properties

```
>>> outRas = Slope(inRaster, "DEGREE", 0.3048)
>>> outRas.
```

- 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
The Ash Borer model

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Demo
Data management and accessing the capability

- Raster management tools
- Raster Calculator
- Python window
- Model Builder
- Simple expression
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- Full modeling control: NumPy arrays
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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

\[
inRaster = \text{ExtractByAttributes}(\text{inElevation}, \ "Value > 1000")
\]

\[
out = \text{Con}(\text{IsNull}(\text{inRaster}), 0, \text{inRaster})
\]
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

  ```plaintext
  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
Demo

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

![Syntax](image-url)

<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>
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</tr>
<tr>
<td>units</td>
<td>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)</td>
<td>String</td>
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![Properties](image-url)

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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
  
  \texttt{neigh = NbrCircle(4, "MAP")}

- Querying
  
  \texttt{radius = neigh.radius}

- Changing arguments
  
  \texttt{neigh.radius = 6}
Classes composed of lists

• Topo
  
  \[
  \text{inContours} = \text{TopoContour}([['\text{contours.shp}', 'spot\_meter']])
  \]

• Reclassify
  
  \[
  \text{remap} = \text{RemapValue}(["\text{Brush/transitional}", 0],
  ["\text{Water}", 1],["\text{Barren land}", 2])
  \]

• Weighted Overlay

  \[
  \text{myWOTable} = \text{WOTable}([\text{inRaster1}, 50, "VALUE", remapsnow],
  \text{[inRaster2, 20, "VALUE", remapland]},
  \text{[inRaster3, 30, "VALUE", remapsoil]}], [1, 9, 1])
  \]
Vector integration

- Feature data is required for some Spatial Analyst Map Algebra
  - IDW, Kriging, etc.

- Geoprocessing tools that operate on feature data can be used in an expression
  - Buffer, Select, etc.

```python
dist = EucDistance(arcpy.Select_analysis("schools", "#", "Pop>2000"))
```
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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
Demo

Movement by flight

20 km per year
Vegetation type/ash density (suitability)
Classes
Using variables
Vector integration
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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
The Ash Borer model

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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
def getABlocks(arrayL): 
    ind = arrayL.nonzero()
    return ind

def randomABMovement(arrayABlocks, arrayA, maxDist):
    # Get current Ash Borer locations from array (1 = infested; 0 = not in ABlocations = getABlocks(arrayABlocks)
    # Reduce array for every third
    ABlocations = ABlocations[0::3], ABlocations[1::3]
    nlocs = len(ABlocations[0])
    # For each input AB location
    for i in range(nlocs):
        p = ABlocations[0][i][1], ABlocations[1][i][1]
        arcpy.AddMessage("current location: %s %s")%(str(p)))
        # Test three random movements
        for l in range(3):
            # 1. Generate random movement distance.
            randomXYdist = getRandomXYDist(maxDist)
            # 2. New location for Ash Borer movement
            Allocation_new = p[0] - randomXYdist[0], p[1] + randomXYdist[1]
            arcpy.AddMessage("new location to %s %s")%>(str(Allocation_new)))
            # 3. If new location is susceptible AB Infest = TRUE
            Allocation_new != 1:
            allocation_new = 0;
            allocation_new = 1
            e("Infested")
            ("Not Infested")

            mean. It should be nonzero.

x = int(random.expovariate(1.0/lambda))
while y < - maxDist or y > maxDist:
    y = int(random.expovariate(1.0/lambda))
    y = int(random.expovariate(-1.0/lambda))

----------

Demo

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
Other Spatial Analyst sessions

- **Spatial Analyst: An Introduction**
  - Tues 10:15 – 11:30
  - Wed 10:15 – 11:30

- **Finding the Best Locations Using Suitability Modeling**
  - Tues 1:30 – 2:45
  - Thurs 8:30 – 9:45

- **Identifying the Best Paths with Cost Distance**
  - Tues 3:15 – 4:30
  - Wed 1:30 – 2:45

- **Suitability Modeling and Cost Distance Analysis Integrated Workflow (Demo Theater)**
  - Wed 4:30 – 5:15

- **Python: Raster Analysis**
  - Tues 8:30 – 9:45

- **Getting Started With Map Algebra Using the Raster Calculator and Python (Demo Theater)**
  - Thurs 9:30 – 10:15
Other Spatial Analyst sessions

- **Modeling Renewable Energy Potential Using ArcGIS (Demo Theater)**
  - Tues 1:30 – 2:15

- **Creating Watersheds and Stream Networks**
  - Wed 10:00 – 10:30

- **Hydrologic and Hydraulic Modeling**
  - Wed 3:15 – 4:30
  - Thurs 1:30 – 2:45

- **GIS Techniques for Floodplain Delineation (Demo Theater)**
  - Tues 12:30 – 1:15

- **Creating a Hydrologically Conditioned DEM (Demo Theater)**
  - Tues 10:30 – 11:15

- **Creating Surfaces from Various Data Sources**
  - Tues 3:15 – 4:30
  - Thurs 3:15 – 4:30

- **Choosing the Best Kriging Model for Your Data (Demo Theater)**
  - Wed 11:30 – 12:15
Other Spatial Analyst sessions

- **Surface Interpolation in ArcGIS (Demo Theater)**
  - Thurs 10:30 – 11:15

- **Creating Watersheds and Stream Networks (Demo Theater)**
  - Wed 10:00 – 10:30

- **Working with Elevation Services (Demo Theater)**
  - Tues 10:30 – 11:15
  - Wed 9:30 – 10:15

- **Building Python Raster Functions (Demo Theater)**
  - Tues 10:30 – 11:15

- **Raster Analytics in Image Server: An Introduction**
  - Wed 3:15 – 4:30

- **Raster Classification with ArcGIS Desktop (Demo Theater)**
  - Thurs 9:30 – 10:15

- **Raster Function Processing (Demo Theater)**
  - Thurs 10:30 – 11:15
Want to learn more?

- **Documentation**
  - [ArcGIS Pro Help](#)
  - [Terminology and user interface reference guide](#)

- **Related Esri Training and Tutorials**
  - [Introduction to ArcGIS Pro for GIS Professionals (Instructor Led)](#)
  - [Getting Started with ArcGIS Pro (Virtual Campus)](#)
  - [Get Started with ArcGIS Pro (Learn ArcGIS)](#)

- **Additional Resources**
  - [ArcGIS Pro Site](#)
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