ArcPy: Working with Raster Data

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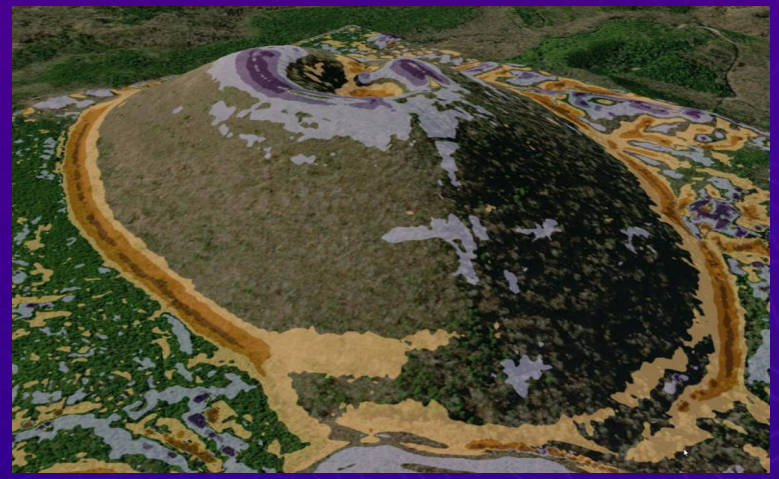
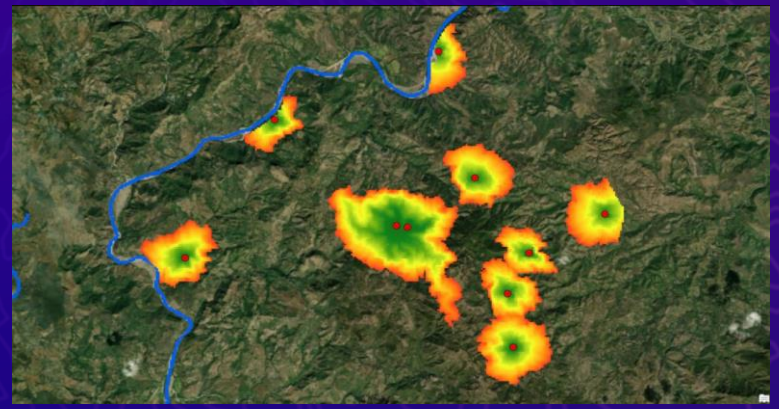
2023 ESRI USER CONFERENCE

Outline

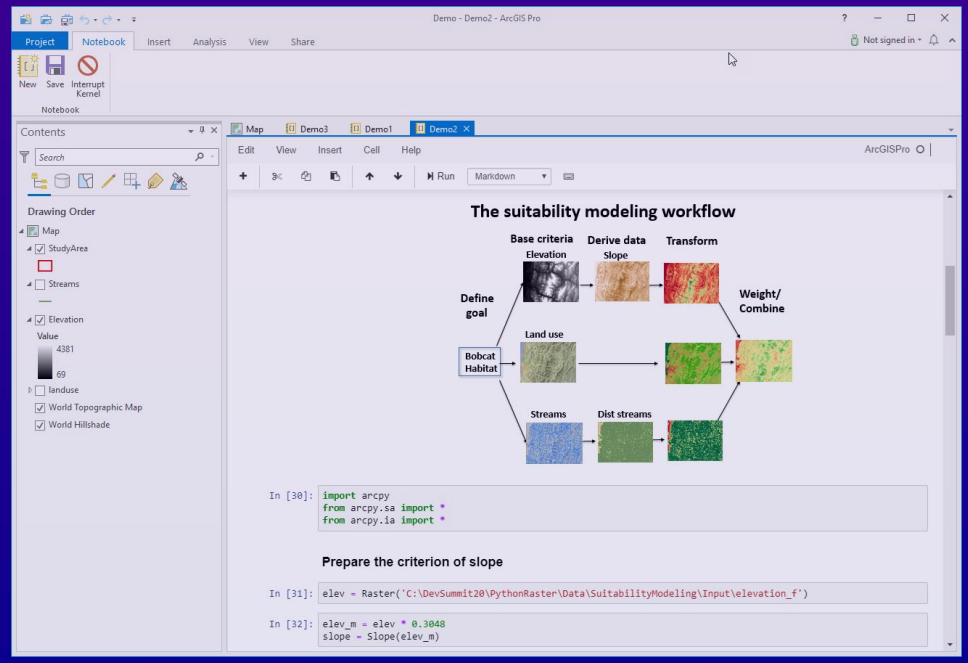
- What can you do with raster in Python?
- ArcPy modules for raster analysis
- Raster object
- Visualization and exploration of raster data
- Raster data management and processing
- Raster analysis
- NumPy array and custom analysis





What can you do with raster using ArcPy?

- Visualization and exploration
- Data preprocessing, data management
- Batch processing, workflow automation
- Raster analysis
- Customized raster analysis



Python APIs for Raster Processing in ArcGIS

- ArcGIS API for Python
  - ArcGIS Enterprise / ArcGIS Online
  - Remote processing

- ArcPy
  - Desktop App (ArcGIS Pro)
  - Local processing

ArcPy: Over 1300+ Comprehensive GIS Functions

Data Management

- Convert between formats, 2D <-> 3D, build topology, data reviewer, linear referencing,
- data comparison, manage spatial databases, distributed editing, servers & services
- **Specialized datasets** – parcels, utility networks, address locators, network datasets

Location analytics

- **business intelligence** – market penetration, Huff model, suitability analysis, territory design,
- **Network** – routing, OD cost matrix, service area, location allocation
- **Geocoding** – batch, reverse, composite

Raster Analysis

- Extraction, overlay, proximity, distance, hydrology, multivariate, map algebra, neighborhood, fuzzy overlays

Cartography

- annotations, generalization, map series, masks
- **100+** projections and transformations
- **editing tools** – conflation, densify, cartographic refinement
- Layouts, printing, map series

3D

- LAS classification, extraction, terrain, TIN, DEM, DSM, volume analysis
- **Surface analysis** – aspect, contour, cut fill, hillshade, slope, line of sight, sun shadow, viewshed, hydrology

Imagery analysis

- **management** – mosaic datasets, raster algebra,
- **ortho mapping** – point cloud, stereo model, photogrammetry, surface creation, ortho rectification
- **information extraction** – classification, object detection, segmentation, spectral analysis, statistics
- Full motion imagery, multidimensional rasters, solar radiation
- Hundreds of math and stat tools

Spatial Machine Learning

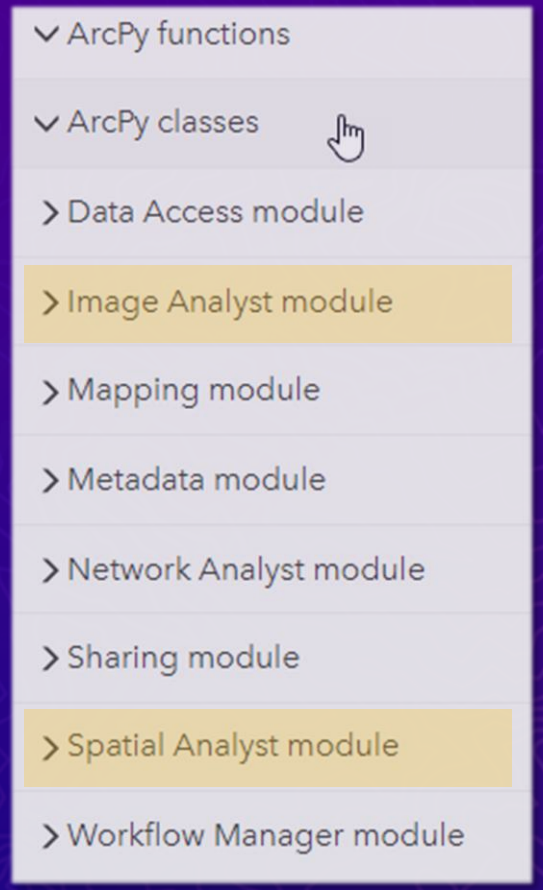
- **Interpolations**, spatial sampling, simulations,
- **Stats** – enrich, density, hot spot, clustering, autocorrelations, balanced zones, outliers, similarity search, local bivariate relationships
- **Prediction** – random forests, GLR, OLS, GWR, validation
- **Pattern mining** – emerging hot spot, time series clustering,
- **Big Data** – GeoAnalytics desktop tools
- **Deep Learning** – classify objects, classify pixels, detect objects, export training data, train model

ArcPy ia and sa Modules

- Modules of ArcPy for raster analysis and image processing
- Like all modules must be imported
- How you import is important to access the operators and tools in an algebraic format

```
import arcpy
from arcpy import env    # Analysis environment
from arcpy.sa import *   # BEST Practice for Map Algebra
from arcpy.ia import *   # BEST Practice for Map Algebra
```

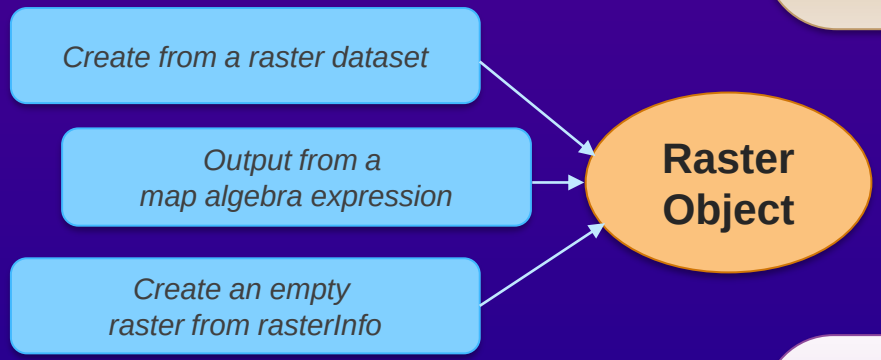
```
import arcpy.sa    # NOT Recommended for Map Algebra
```



Raster Object

- Represents a raster in arcpy
  - Single-band raster, multi-band raster, multidimensional raster
- Output from a Map Algebra expression, pointing to an existing dataset, or an empty raster created using rasterInfo
- Output from Map Algebra or an empty raster is temporary and can be persisted using the save method
- Many properties describe the associated dataset
- Many methods to work with properties, bands, multidimensional variables, dimensions, slices
- Read/Write methods to convert raster to a NumPy array and to create a raster from NumPy array

Raster Object



Raster (inRaster, {is_Multidmensional})

Properties

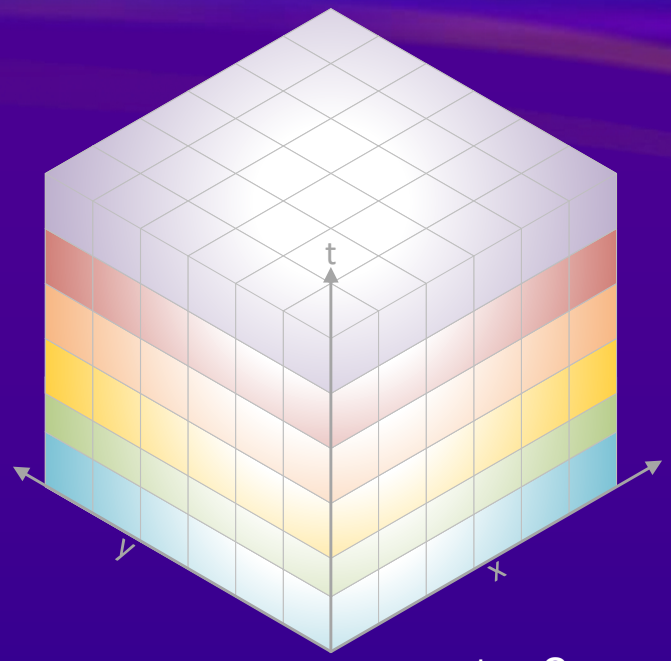
- properties
- catalogPath
- path
- name
- isTemporary
- readOnly
- isInteger
- hasRAT
- hasTranspose
- isMultidimensional
- bandCount
- bandNames
- extent
- width
- height
- meanCellWidth
- meanCellHeight
- spatialReference
- maximum
- mean
- minimum
- standardDeviation
- noDataValue
- noDataValues
- RAT
- mdinfo
- variableNames
- variables
- slices
- format
- pixelType
- compressionType
- uncompressedSize
- blockSize

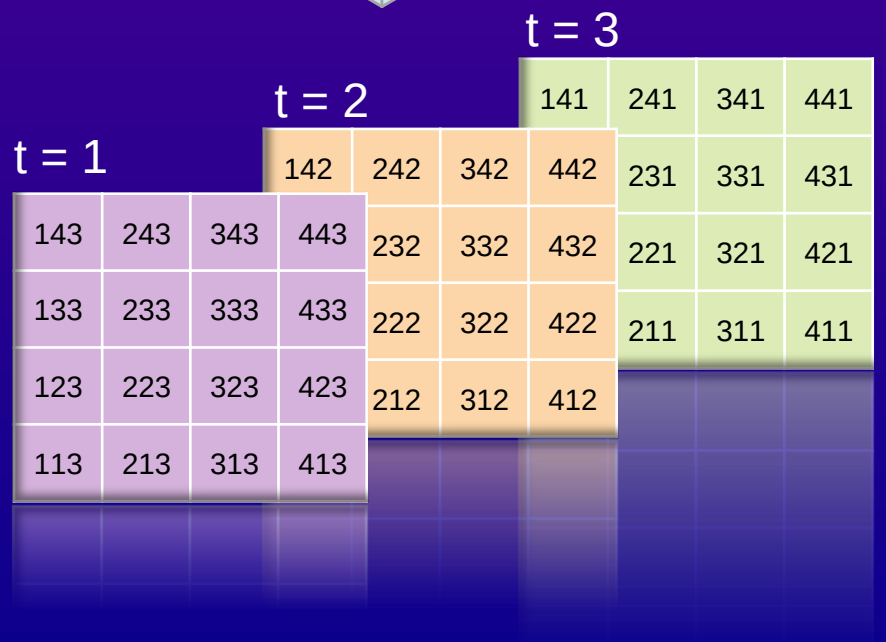
Methods

- save
- exportImage
- getProperty
- setProperty
- getRasterInfo
- getRasterBands
- getVariableAttributes
- renameVariable
- removeVariables
- setVariableAttributes
- getDimensionNames
- getDimensionAttributes
- getDimensionValues
- addDimension
- read
- write

Multidimensional Raster

- Spatial, temporal, and vertical dimensions
- Contains one or multiple variables in one file
  - A variable is cube or cubes
  - A variable has a time and/or depth
  - Each slice is a 2D array
- Multidimensional Raster
  - A Mosaic Dataset
  - Or a Raster Dataset





Visualization and Exploration

- Render function displays a raster object by applying symbology

  arcpy.ia.Render (in_raster, {rendering_rule}, {colormap})

  arcpy.sa.Render (in_raster, {rendering_rule}, {colormap})

- There are other functions to control appearance

- Raster object has several properties and method to explore raster dataset
  - isInteger
  - hasRAT
  - isMultidimensional
  - bandCount
  - bandNames
  - extent
  - width
  - height
  - meanCellWidth
  - meanCellHeight
  - spatialReference
  - maximum
  - mean
  - minimum
  - standardDeviation
  - noDataValue
  - noDataValues

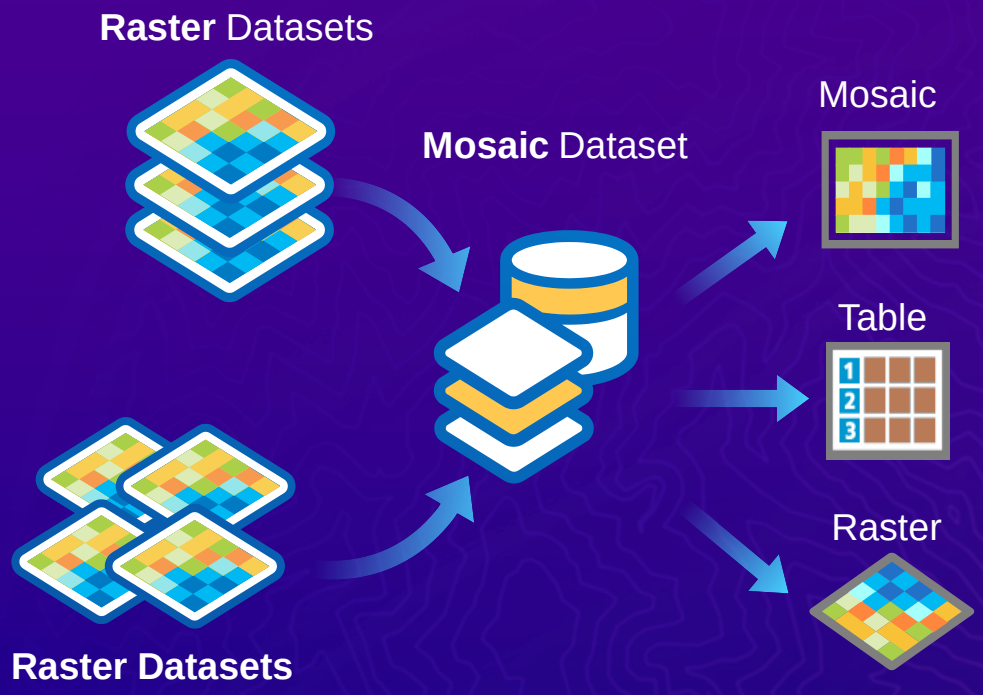
Raster Data Management and Batch Processing

Function	Description
ApplyEnvironment	Creates a new raster that is a copy of the input raster with the current environment settings being applied.
Clip	Creates a raster object that is clipped according to the extent of an input raster dataset or the shape of an input polygon feature class.
CompositeBand	Creates a raster object by combining multiple rasters to form a multiband image.
ExtractBand	Creates a raster object by extracting one or more bands from, or reordering the bands in, a multiband raster.
Mask	Creates a raster object by specifying one or more NoData values or a range of valid pixel values.
Merge	Creates a raster object by merging a list of rasters spatially or across dimensions.
Resample	Creates a raster object by changing the spatial resolution of the input raster and sets rules for aggregating or interpolating values across the new pixel sizes.
Subset	Creates a raster object that is a subset of the input multidimensional raster based on selected variables and dimension intervals.
TransposeBits	Creates a raster object by unpacking the bits of the input pixel and mapping them to specified bits in the output pixel. The purpose of this function is to manipulate bits from a couple of inputs, such as the Landsat 8 quality band products.

arcpy.ListRasters ({wild_card}, {raster_type})

Raster Data Management in ArcGIS

- Raster Dataset
  - Represent single dataset
- Mosaic Dataset
  - Dynamic mosaic of imagery collection
  - Table of records
  - A Raster Dataset
  - Lives in Geodatabase



CreateMosaicDataset(in_workspace, in_mosaicdataset_name, coordinate_system, {num_bands}, {pixel_type}, {product_definition}, {product_band_definitions})

AddRastersToMosaicDataset(in_mosaic_dataset, raster_type, input_path, {update_cellsize_ranges}, {update_boundary}, {update_overviews}, {maximum_pyramid_levels}, {maximum_cell_size}, {minimum_dimension}, {spatial_reference}, {filter}, {sub_folder}, {duplicate_items_action}, {build_pyramids}, {calculate_statistics}, {build_thumbnails}, {operation_description}, {force_spatial_reference}, {estimate_statistics}, {aux_inputs}, {enable_pixel_cache}, {cache_location})

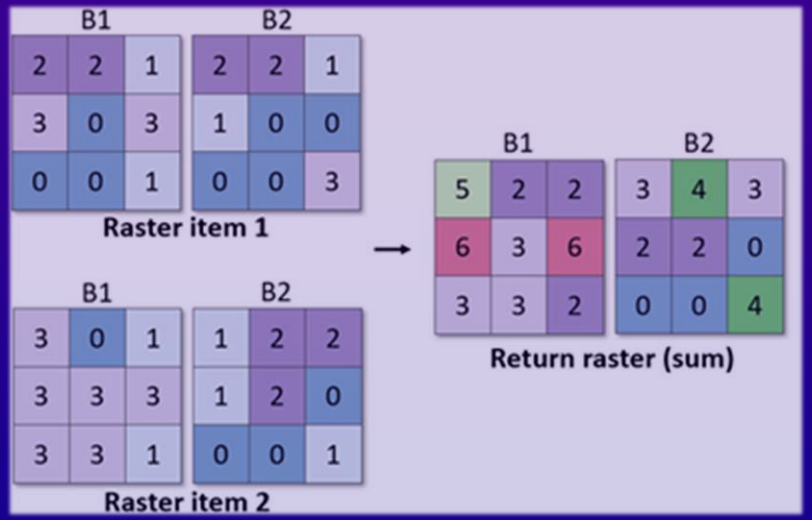
RasterCollection

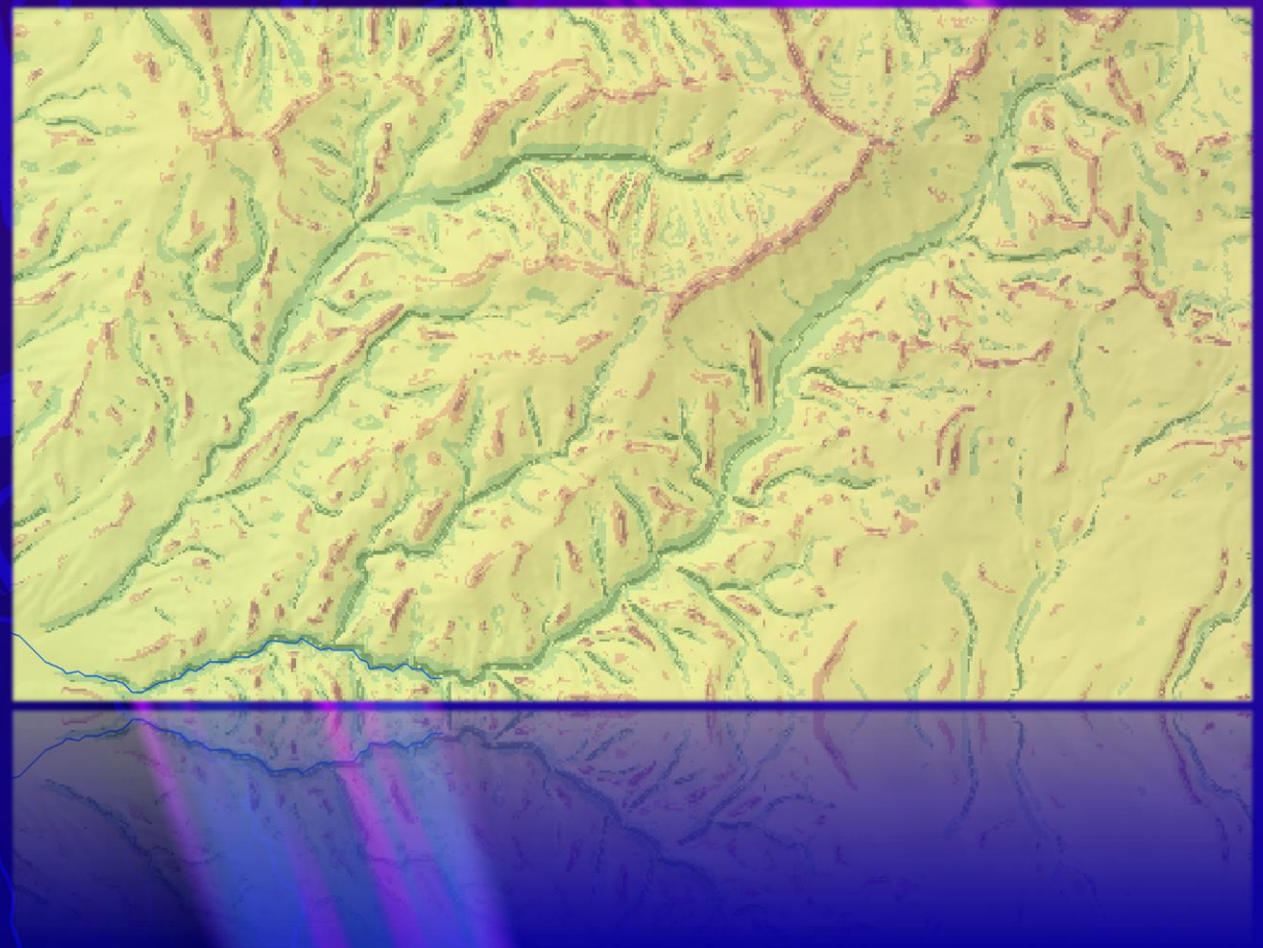
- Defines the group of input rasters and attributes to include in a collection, which will be used for processing.

  RasterCollection (rasters, {attribute_dict})

Properties
- fields
- count

Methods
- filter
- filterByAttribute
- filterByCalendarRange
- filterByGeometry
- filterByRasterProperty
- filterByTime
- getFieldValues
- majority
- map
- max
- mean
- median
- min
- mosaic
- qualityMosaic
- selectBands
- sort
- sum
- toMultidimensionalRaster





Reading, Visualizing, and Preprocessing

Sarmistha Chatterjee

- Read raster data
- Explore raster data properties
- Visualize raster data
- Raster data preprocessing
- Batch processing

Raster Analysis using Map Algebra

- Simple and powerful algebra to execute tools, operators, and functions to perform raster analysis
  - Comprised of input data, operators, tools, functions, parameters and output
  - output raster is specified to the left of an equal sign and
  - the tool and its parameters on the right
- The strength is in creating complex expressions
- Tools, operator and functions are available in Spatial Analyst and Image Analyst modules
- You can specify analysis environment using arcpy.env

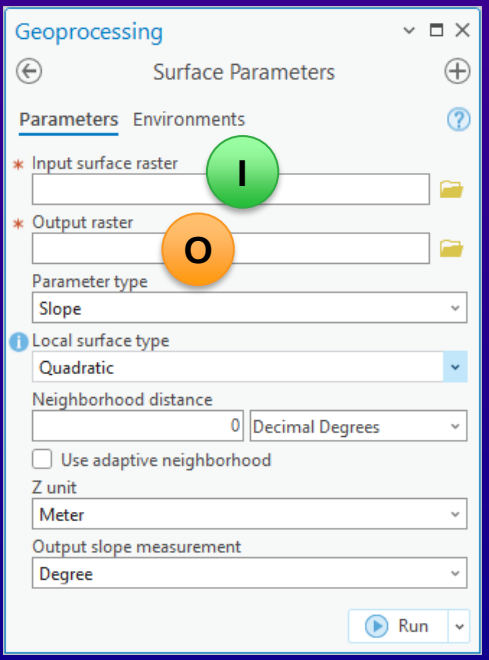
Map Algebra Tools and Functions

- All Spatial Analyst and Image Analyst tools are available (e.g., Sin, Slope, Reclassify, etc.)
- Additional functions are available in arcpy.ia and arcpy.sa modules
- Spatial Analyst and Image Analyst tools/functions will require to checkout license
- Can use any Geoprocessing tools
- Each tool has its own unique set of parameters
- Some are required, others are optional
- Numbers, strings, and objects (classes)

SurfaceParameters(in_raster, {parameter_type}, {local_surface_type}, {neighborhood_distance}, {use_adaptive_neighborhood}, {z_unit}, {output_slope_measurement}, {project_geodesic_azimuths}, {use_equatorial_aspect})

I

O outSurfaceParameters = SurfaceParameters("elevation_1m.tif", "", "", "5 METERS", "ADAPTIVE_NEIGHBORHOOD", "", "PERCENT_RISE")



Map Algebra Operators

- Symbols for mathematical operations
- Many operators in both Spatial Analyst and Image Analyst

```
outRas1 = inRaster1 + inRaster2
```

- Cast the raster (Raster class constructor) to indicate operator should be applied to rasters

```
outRas1 = Raster("rastername1") + Raster("rastername2")
outRas2 = Raster("rastername1") + 8
outRas3 = outRas2 + Raster("rastername2") * 8
```

Map Algebra Output

- Returns the results as a Raster object
- The output is temporary
- Make it permanent by calling the save method

```
save ({name})
outSurfaceParameters = SurfaceParameters("elevation_1m.tif", "", "", "5 METERS",
                                         "ADAPTIVE_NEIGHBORHOOD", "", "PERCENT_RISE")
outSurfaceParameters.save("mySlopeOutput.tif")
```

Complex Expressions and Optimization

- Multiple operators and tools can be executed in a single expression
- Output from one expression can be the input to a subsequent expression
- A series of local tools (Abs, Sin, Cell Statistics, etc.) and operators can be optimized
  - Operators and local tools work on a per-cell basis
  - When entered into a single expression all local tools and operators are processed together on a per cell basis

Everything in one complex expression

In [47]:
```
suitability_map = Reclassify(Slope(elev * 0.3048),
                             "Value",
                             RemapRange([[0,3,1], [3,10,3], [10,25,6], [25,90,10]])) * 0.2 + \
                  Reclassify(landuse,
                             "Value",
                             RemapValue([[4,2], [11,10], [1,1], [3,1], [2,1], [7,10],
                                         [6,10] ,[8,10], [5,8], [9,6], [12,1], [10,2]])) * 0.5 + \
                  RescaleByFunction(DistanceAccumulation(arcpy.Clip_analysis("Streams",
                                                                             "StudyArea",
                                                                             "#")),
                                    TfMSSmall(), 1, 10) * 0.3
```

Classes

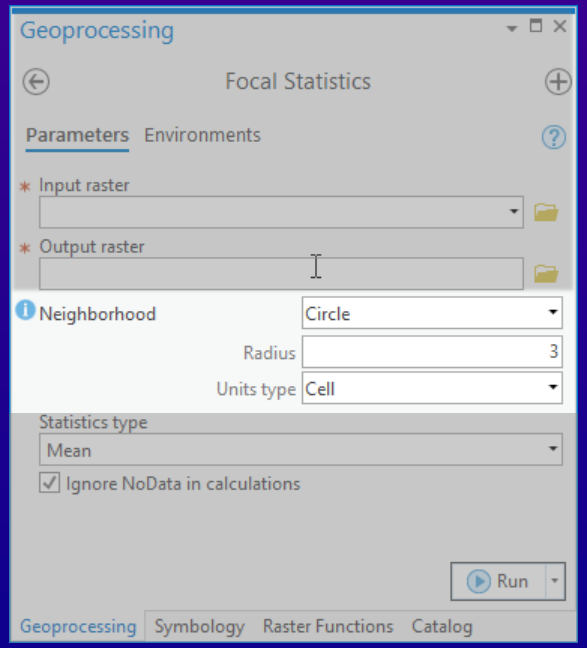
- Objects that are used as inputs to tools
  - Varying number of arguments depending on the selected parameter choice (neighborhood type)
  - The number of entries into the parameters can vary depending on the specific situation (a remap table)
- More flexible, you can query and modify the individual arguments

- Creating

  nbr01 = NbrCircle(4, "MAP")
- Querying

  radius01 = nbr01.radius
- Changing arguments

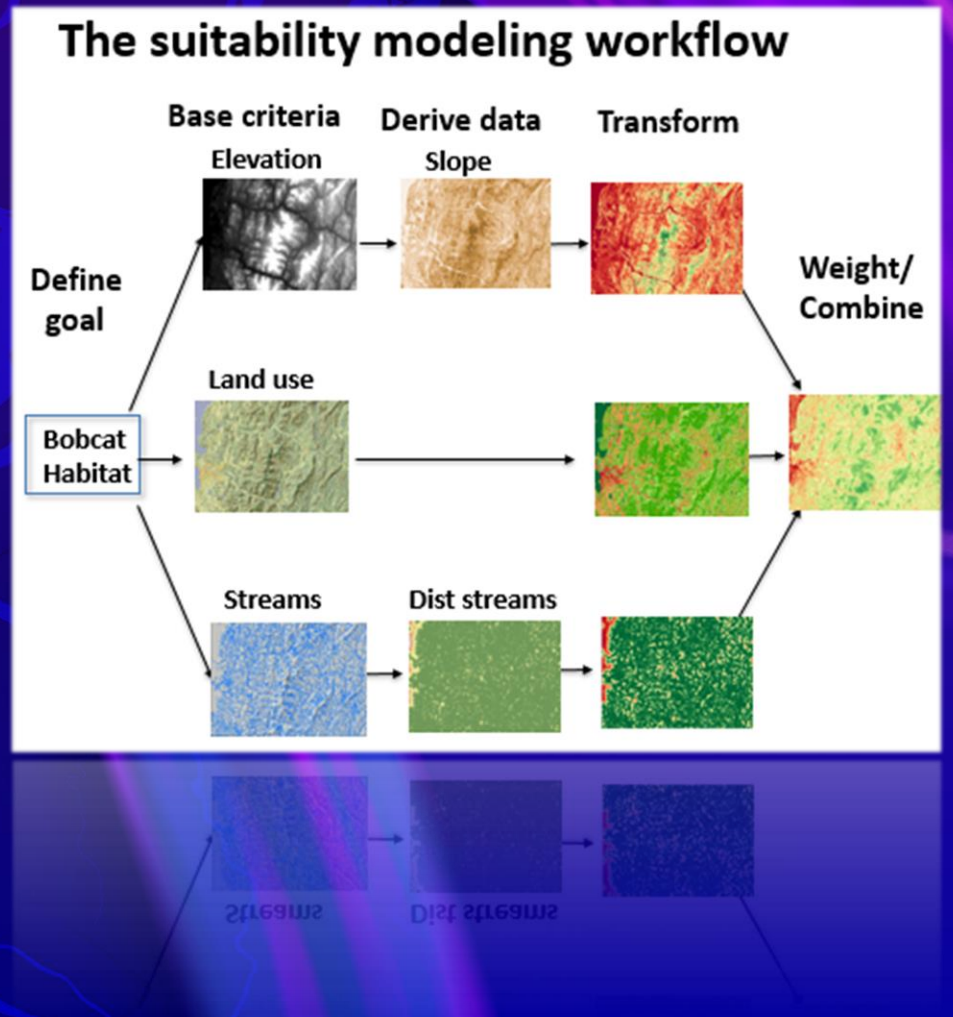
  nbr01.radius = radius01 + 2



Feature Data Integration

- Feature data is required for some raster analysis
  - IDW, Kriging etc.
- Geoprocessing tools that operate on feature data can be used in an expression
  - Buffer, Select, etc.

rivbuff = arcpy.Buffer_analysis(arcpy.RasterToPolyline_conversion(riv,'#'),'rivbuff.shp',100)



Raster Analysis

Tania Lopez-Cantu

- Simple map algebraic expression
- Functions and complex parameters
- Analysis environment settings
- Complex map algebraic expressions

NumPy

- Can be used to extend raster analysis capabilities by creating
  - custom functions
  - custom tools

- An extension package to Python
  - Adds support for large, multi-dimensional arrays
  - Provides a large library of high-level mathematical functions

- Access the wealth of free functions built by the scientific community
    - Clustering
    - Filtering
    - Linear algebra
    - Optimization
    - Fourier transformation
    - Morphology

NumPy Arrays

- Two functions to work with raster

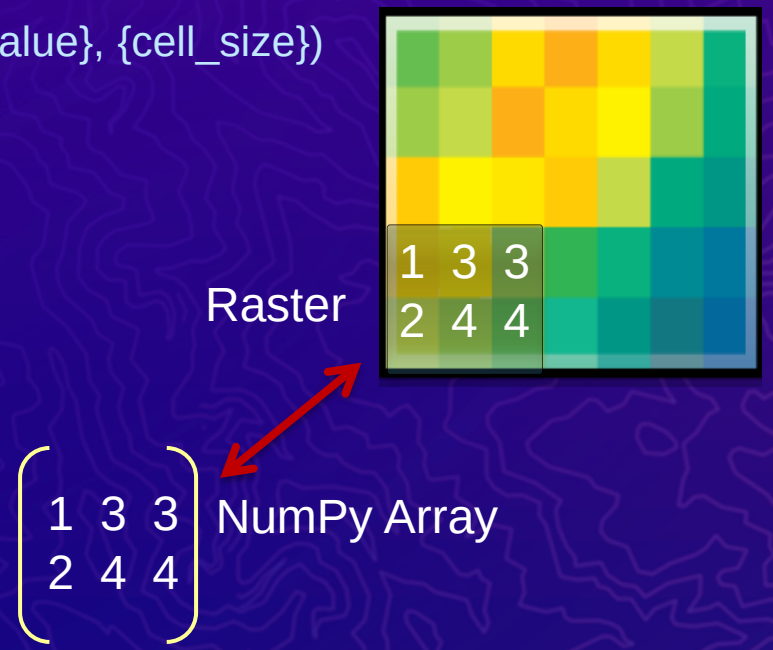
  RasterToNumPyArray(in_raster, {lower_left_corner}, {ncols}, {nrows}, {nodata_to_value})

  NumPyArrayToRaster (in_array, {lower_left_corner}, {x_cell_size}, {y_cell_size}, {value_to_nodata})

- Raster object Read and Write methods

  read ({upper_left_corner}, {origin_coordinate}, {ncols}, {nrows}, {nodata_to_value}, {cell_size})

  write (array, {upper_left_corner}, {origin_coordinate}, {value_to_nodata})



PixelBlock and PixelBlockCollection

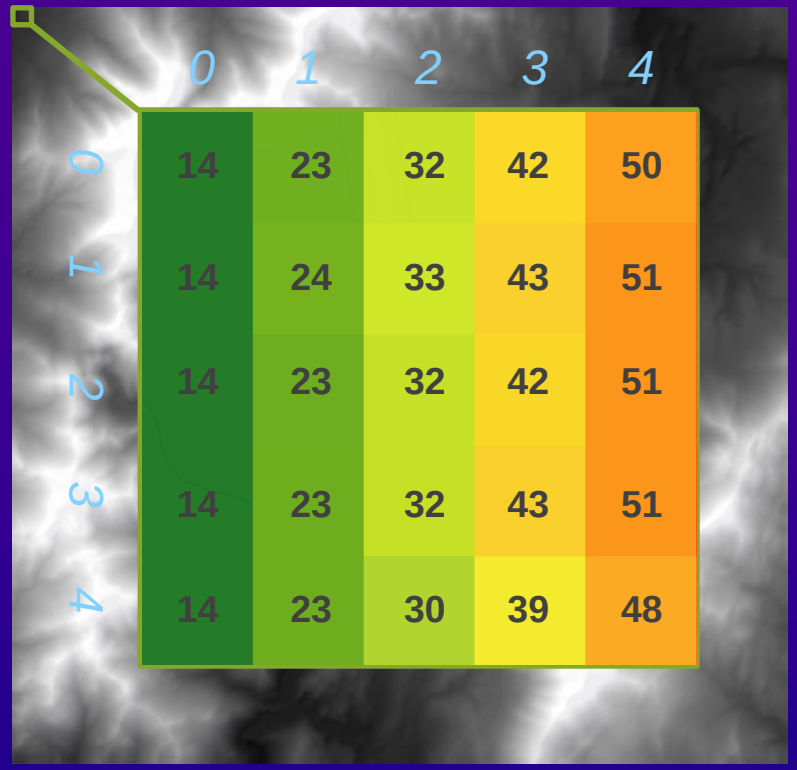
- The PixelBlock object defines a block of pixels within a raster to use for processing. It is used in conjunction with the PixelBlockCollection object to iterate through one or more large rasters for processing.
- getData () method returns a NumPy array within the extent

  PixelBlock (data, extent)

- The PixelBlockCollection object is an iterator of all PixelBlock objects in a raster or a list of rasters. It can be used to perform customized raster processing on a block-by-block basis, when otherwise the processed rasters would be too large to load into memory.

  PixelBlockCollection (in_rasters, pixel_block_size, stride, overlay_type, nodata_to_values)

Raster Cell Iterator (RCI)



- Visit each cell in a Raster object by row/column indices and read/write cell values
- Support iterating multiple raster datasets and perform analysis at the same location
- Access to cell values at each location and neighboring locations is efficient
- Available through the Spatial Analyst module

arcpy.sa.RasterCellIterator(*args),

*args is a dictionary that defines rasters and padding in the following format:

{'rasters': [in_rasterobj1, in_rasterobj2, ...], 'padding': padding_factor, 'skipNoData': [in_rasterobj1, in_rasterobj2, ...]}

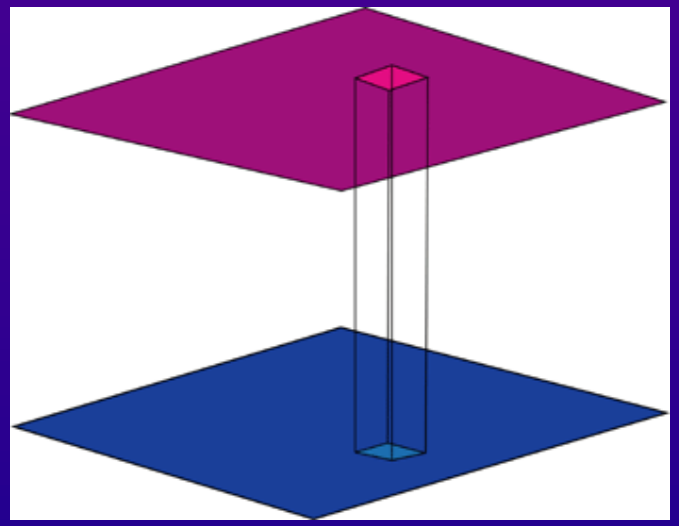
Customize Raster Analysis

Tania Lopez-Cantu

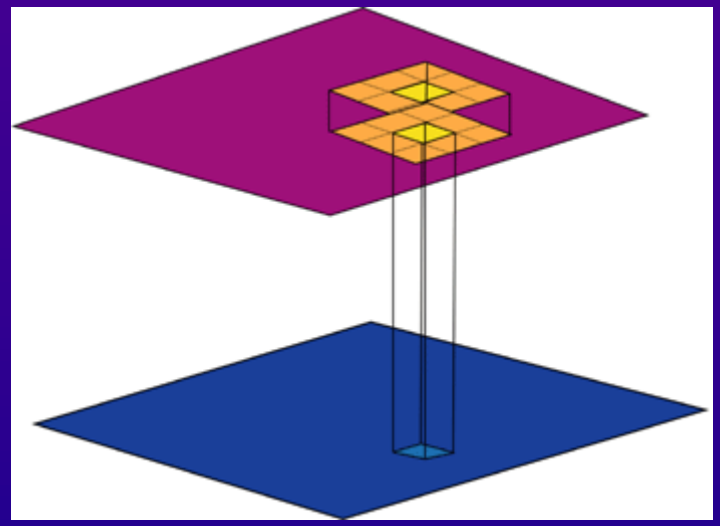
- Raster Cell Iterator (RCI) basics
- Customize raster analysis using RCI and NumPy
- Share customized analysis

Raster Analysis using Multiprocessing

- Types of raster operations:
  - Local
  - Focal
  - Zonal
  - Global

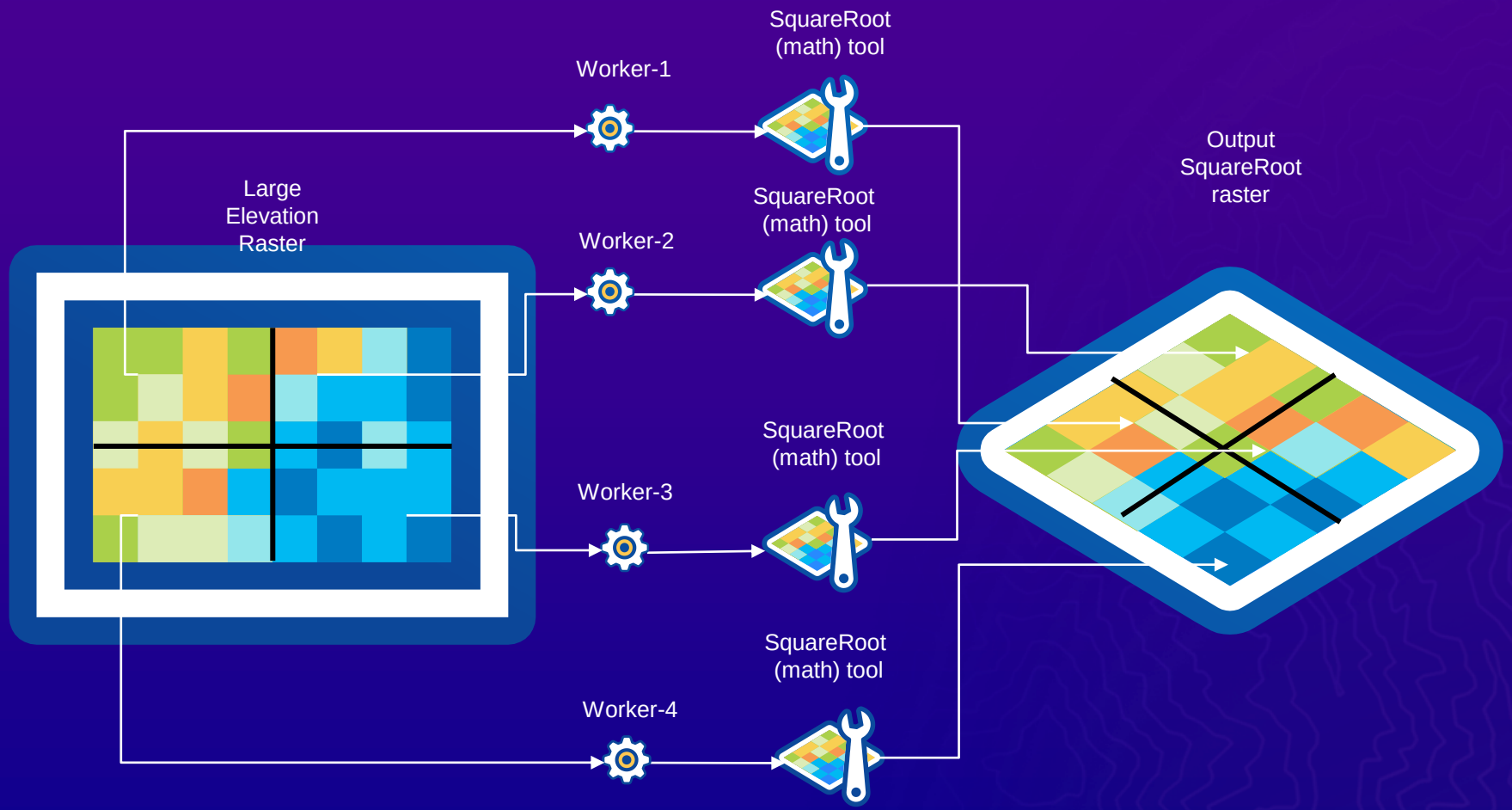


Local raster operation



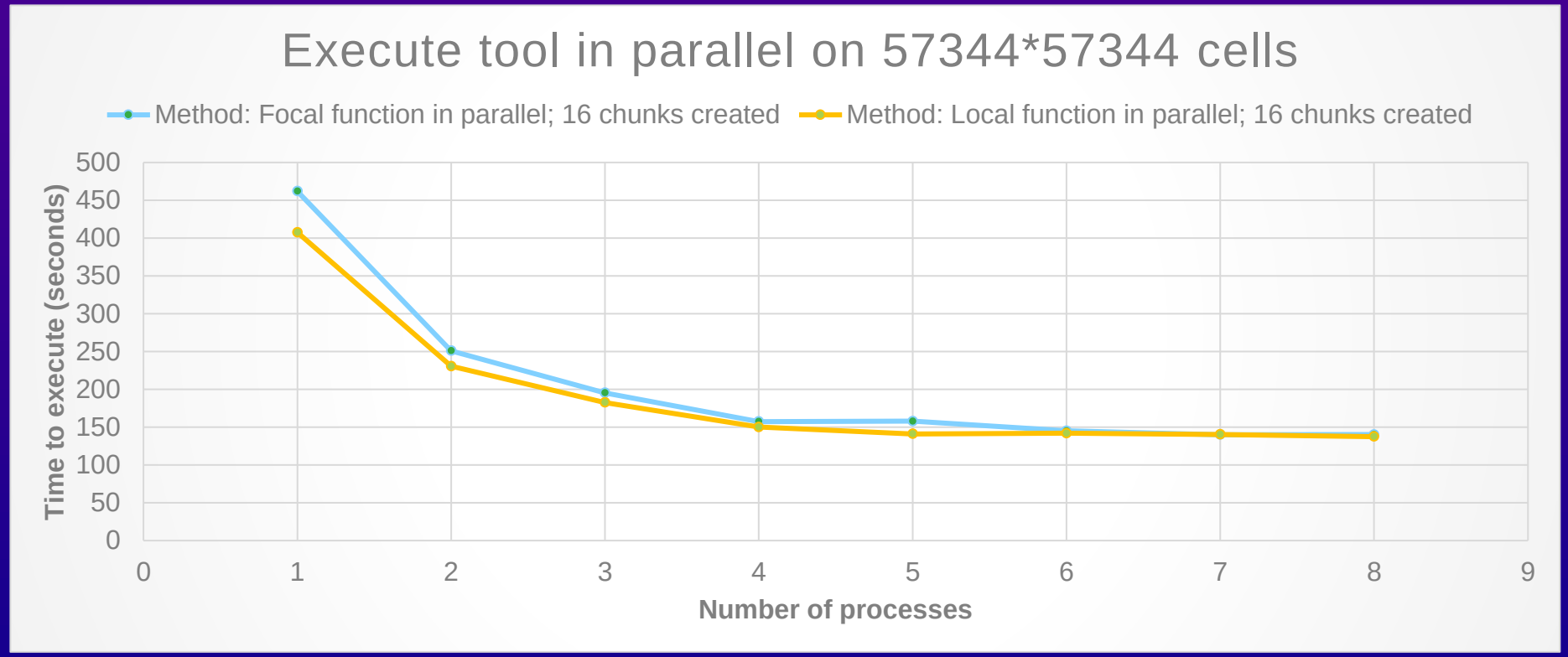
Focal raster operation

Pleasingly Parallel Problems



Tool executed parallelly on a large input dataset

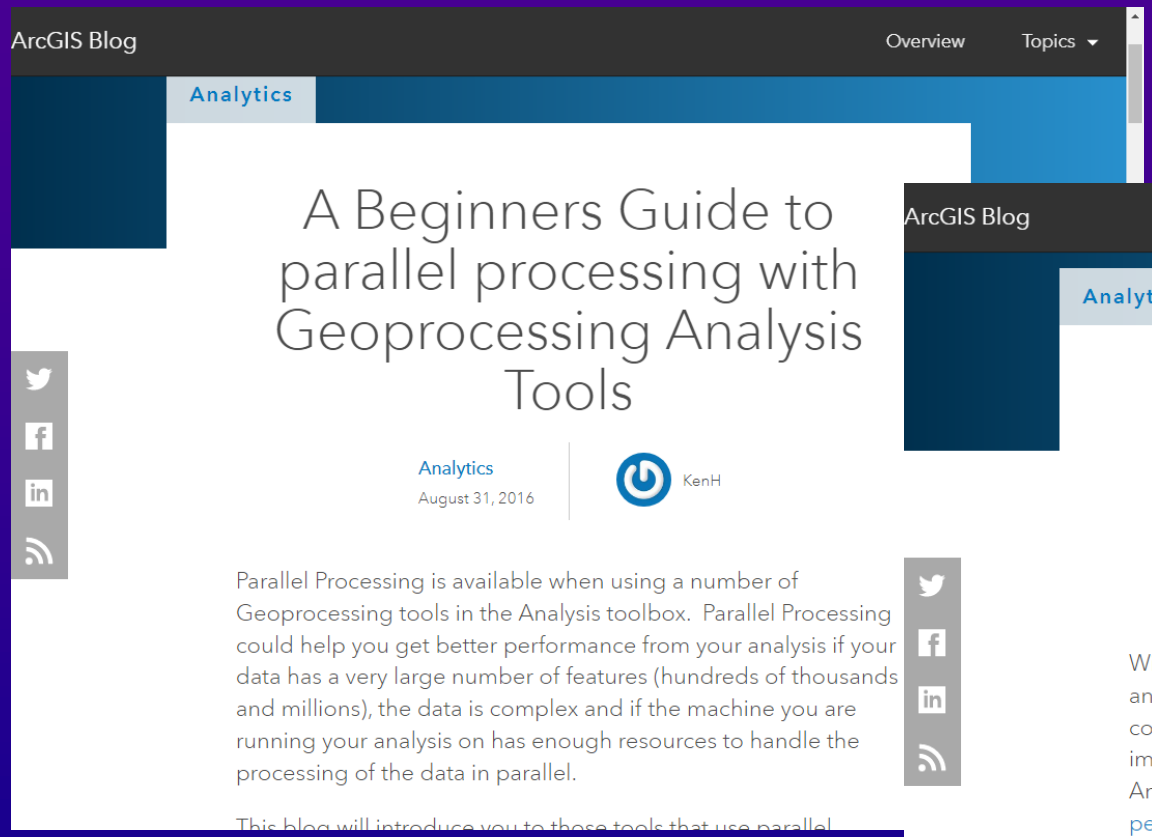
Performance Improvement using Multiprocessing

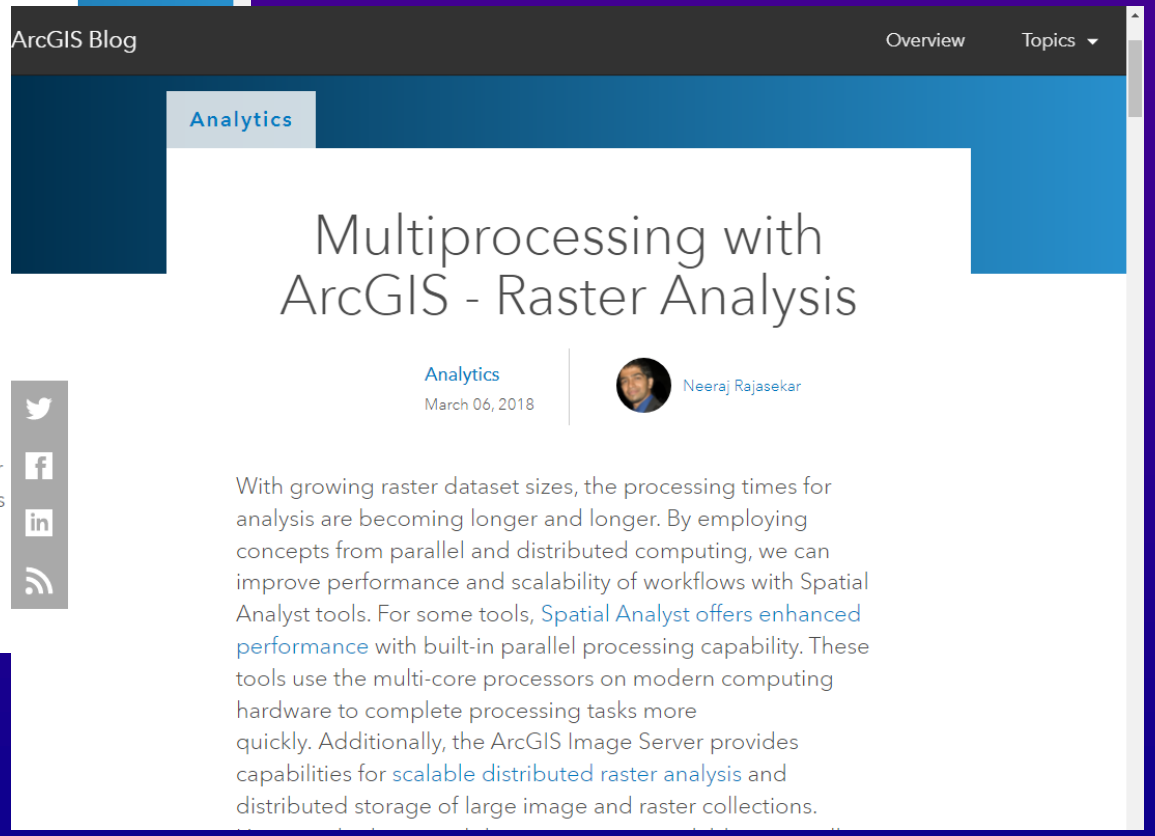


Use of Multiprocessing for Raster Analysis

```
if __name__ == '__main__':
    #start the clock
    time_start = time.clock()
    # call create fishnet functionlarge6insectlkuk
    logger.info("Creating fishnet features..")
    create_fishnet(in_raster_path,out_fishnet_path)
    #get extents of individual features, add it to a dictonary
    extDict = {}
    count = 1
    for row in arcpy.da.SearchCursor(out_fishnet_path, ["SHAPE@"]):
        extent_curr = row[0].extent
        ls = []
        ls.append(extent_curr.XMin)
        ls.append(extent_curr.YMin)
        ls.append(extent_curr.XMax)
        ls.append(extent_curr.YMax)
        extDict[count] = ls
        count+=1
    # create a process pool and pass dictonary of extent to execute task
    pool = Pool(processes=cpu_count())
    pool.map(execute_task, extDict.items())
    pool.close()
    pool.join()
    #add results to mosaic dataset
    arcpy.env.workspace = os.getcwd()
    in_path = os.path.join(os.getcwd(), r"local_rast_wspace")
    arcpy.AddRastersToMosaicDataset_management("mosaic_out.gdb\localFn_Mosaic", "Raster Dataset", in_path)
    #end the clock
    time_end = time.clock()
    logger.info("Time taken in main in seconds(s) is : {}".format(str(time_end-time_start)))
```

Use of Multiprocessing for Raster Analysis





Summary

- You can visualize, explore, manage, analyze and share raster data using ArcPy.
- Use ArcPy ia and sa modules primarily to work with raster and imagery.
- Raster object represents a raster and provides many useful properties and methods for single-band raster, multi-band raster, and multidimensional raster.
- Map Algebra is a simple but powerful way to perform raster analysis using tools, functions, and operators.
- You can combine raster and vector analysis tools together in an expression.
- Raster object output from map algebra expression is temporary by default. Save it if you need it as a final output.
- You can extend your analytical capability by writing custom code using NumPy, Raster Cell Iterator etc.

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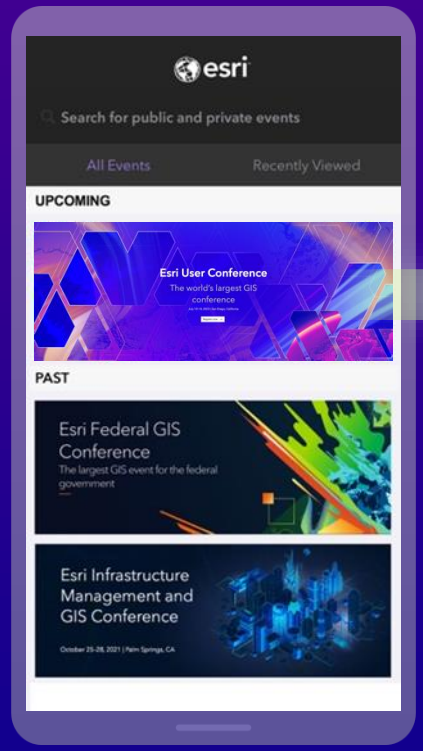
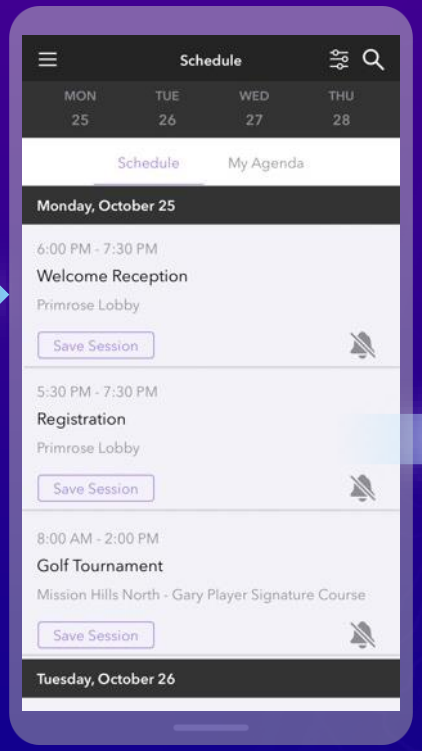
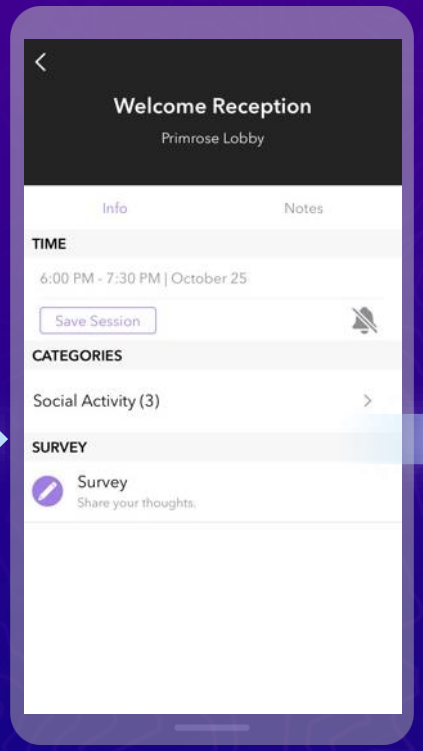


Select the session you attended



Scroll down to “Survey”



Log in to access the survey