Building tools with Python

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A geoprocessing tool does three pieces of work: it defines its parameters, validates its parameters, and executes some code that performs the actual work. This session will focus on the first two pieces—parameters and validation. At the end of this session, you will know how to define parameters using data types, direction, filters, dependencies, and multivalues. You will also gain understanding of how a tool validates its parameters and describes its output for use in ModelBuilder. Armed with this knowledge, you’ll be able to design and build a tool that is robust and useful regardless of what programming language you use for implementation. All concepts will be demonstrated by implementing Python script tools.
Session Evaluations

- www.esri.com/sessionevals
Macros versus Tools

- Geoprocessing = Computing with geographic data
  - quickly and easily turn your ideas into repeatable workflows (software)
- Two basic software types: macro and tool
- A **macro** is tied to a specific set of data
  - A layer with a particular name ("Streets"), geometry type (lines), fields ("CFCC", "Meters")
  - In order to work on another set of data, either the macro code or data must be changed
- A **tool** parameterizes data
  - It is not hard-coded to a particular set of data
  - Handles incorrect data gracefully
Macros and tools in ArcGIS

• You can create macros with:
  - ModelBuilder
  - Python Window

• You can create tools with:
  - ModelBuilder
  - Python Scripts
  - ArcObjects

• Tools that you create are called *custom tools*
  - …and are found in custom toolboxes that you create
## Tool types and categories

<table>
<thead>
<tr>
<th>Tool type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built in tool</td>
<td>These tools are built using ArcObjects and a compiled programming language like *NFT.</td>
</tr>
<tr>
<td>Model tool</td>
<td>These tools are created using ModelBuilder.</td>
</tr>
<tr>
<td>Script tool</td>
<td>These tools are created using the Script tool wizard and run a script file on disk, such as a Python file (.py), AML file (.aml), or executable (.exe or .bat).</td>
</tr>
<tr>
<td>Specialized tool</td>
<td>These tools are rare—they are built by system developers and have their own unique user interface for using the tool. The ArcGIS Data Interoperability extension contains specialized tools.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tool category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>System tools</td>
<td>System tools are those tools built and delivered by ESRI. They are installed by ArcGIS or any of its extension products. Almost all system tools are built-in tools, but you will also find system tools that are script or model tools. For example, the Spatial Statistics tools are all script tools, but since they are built and delivered by ESRI, they are considered system tools.</td>
</tr>
<tr>
<td>Custom tools</td>
<td>Custom tools are built by you. These are most often script or model tools, but they can be built-in tools as well. There are an infinite number of custom tools. You can download custom tools that other users have built by visiting the Model and Script tool gallery found on the Geoprocessing Resource Center. You can access the Geoprocessing Resource Center at <a href="http://resources.esri.com/">http://resources.esri.com/</a>.</td>
</tr>
</tbody>
</table>
Getting help

Help system topics
Everything shown today is discussed in the doc

- This illustration is the 10.0 doc
- Applies to 9.3 as well
- See 9.3 doc for use of arcgis scripting versus arcpy
• 10.0 doc again – these books will help you when building script tools
Demo: Script tool basics
Demo review – Table to html

- GetParameterAsText(index)
  - How parameters are received by the script

- Add Script Tool Wizard
  - Properties can be updated later using Properties dialog

- Parameters
  - Label
  - Data Type
  - Direction (input, output, derived)
  - Required vs. Optional
  - Filters
Demo – Table to html with field choices

- Field data type – setting **Obtained From**
- **MultiValues** are passed to script as a semi-colon delimited string
  - “aaa;bbb;ccc;ddd”
- **Transform to python list with:**
  - `mylist = string.split(";")`
  - `Fields = arcpy.GetParameterAsText(1).split(";")`
### Parameter filters

<table>
<thead>
<tr>
<th><strong>Value List</strong></th>
<th>A list of string or numeric values. Used with String, Long, Double, and Boolean parameter data types.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range</strong></td>
<td>A minimum and maximum value. Used with Long and Double data types.</td>
</tr>
<tr>
<td><strong>Feature Class</strong></td>
<td>A list of allowable feature class types: Point, Multipoint, Polyline, Polygon, MultiPatch, Sphere, Annotation, Dimension. More than one value can be supplied to the filter.</td>
</tr>
<tr>
<td><strong>File</strong></td>
<td>A list of file suffixes. Example: &quot;txt; e00; ditamap&quot;.</td>
</tr>
<tr>
<td><strong>Field</strong></td>
<td>A list of allowable field types: Short, Long, Single, Double, Text, Date, OID, Geometry, Blob, Raster, GUID, GlobalID, XML. More than one value can be supplied to the filter.</td>
</tr>
<tr>
<td><strong>Workspace</strong></td>
<td>A list of allowable workspace types: File System, Local Database, Remote Database. More than one value can be supplied.</td>
</tr>
</tbody>
</table>
Demo: Keywords and Booleans
Demo review

• Keywords:
  - A Value List filter on a string parameter
  - Keywords should be UPPERCASE case, no spaces

• Booleans:
  - always have two keywords
    - The True keyword is listed first, False keyword second
  - In scripting, you can either pass
    - The keywords
    - Python True or False
    - Always received as string

• Be sure to supply a default value
Data types
Data types

- Core concept of GP
- Every data type has:
  - A UI control
  - Built-in validation logic
- Two basic types
  - Datasets
  - Scalar (numbers, strings, simple structures)
- Datasets have corresponding data elements
  - Properties accessed using Describe
  - Lightweight descriptions of the dataset
  - Fields, extent, spatial reference, etc.
Common data types

• Layers (i.e. Feature Layer, Raster Layer, etc)
  - Allows user to pick a layer from the TOC, a dataset on disk, or a .lyr file on disk
  - Cursors will only return selected features in the layer

• Table View
  - Anything represented as a table (Feature Layer, Joined tables, tables on disk, etc)
  - Cursors will only return selected rows (or features) in the table

• Long, Double, String, etc.
• Workspace, folder, file, text file
Data types continued

• All data types have a string representation
  - In ArcObjects, the GPDataType object has a GetAsText() and SetAsText() method

• Some data types have a horrid string representation
  - Spatial Reference, Field Map
  - Use arcpy objects to manipulate these

• What data type to use?
  - Find a tool similar to what you want to do
  - Tool reference page lists the data type
  - Experiment in ModelBuilder
  - See Data types for geoprocessing tool parameters
Demo: Exploring data types
Data types -- review

- Use Create Variable in ModelBuilder to explore the UI of a data type
- Any data type can be made into a multiple value – doesn’t always make sense.
- Composite data types ("field or value") can only be created in ArcObjects
- Feature Set (and Record Set) for interactive entry of features or table rows
Derived output
All tools MUST have output

• ModelBuilder – tool’s output is used as input to another tool

• Two types of output:
  - Required: user specifies the output dataset
  - Derived:
    - No output dataset (a number)
    - Modification of input
    - Output dataset determined by the tool
Derived data

- The output parameter is set to Derived
- Optionally, Obtained From is set
- Examples of derived output:
  - **Get Count**: output = a number
  - **Calculate Field**: output = exact copy of input
  - **Add Field**: output = exact copy of input + a new field
  - **Create Feature Class**: new output as defined by inputs (workspace, name, schema)
Demo: Derived output
Demo review: Scalar values

- All scalar values (numbers, text, etc) are derived
  - example: Get Count
- In script tool wizard, set output to Derived
- Must use setParameterAsText() or SetParameter() in your executable
Demo review – Output same as input

- Example: **Calculate Field**
- In script tool wizard, set output to **Derived and Obtained From** to the input parameter
- **SetParameterAsText()** not needed
  - But good habit to do anyway
Demo review – Modify input schema

- Example: **Add Field**
- In script tool wizard, set output to Derived and Obtained From to the input parameter
- In ToolValidator (coming up next), you’ll modify the output schema to contain the new field
- `SetParameterAsText()` not needed
  - But good habit to do anyway
Demo review – new output

- Example: **Create Feature Class**
- In script tool wizard, set output to Derived, **Obtained From** is blank (empty)
- Optionally, set the schema in ToolValidator (coming up next)
- Use `SetParameterAsText()` in your executable
Validation

Programming the ToolValidator class
Validation is everything that happens…

- Before the OK button is pushed
Parameter properties provide basic validation

- Have all the required parameters been supplied?
- Are the values of the appropriate data types?
- Does the input or output exist?
  - If output exists and OverwriteOutputs is false, throw error, throw warning otherwise
- Do values match their filter?
Full validation

If NEW_FORMAT is chosen...

...three new choices appear

The default cellsize is calculated from the extent of the Input Features parameter.
Full validation (continued...)
Full validation (continued…)

Because the script tool updates the description of its output, the Summary Statistics tool is aware of all the fields even before the script tool is run.
ToolValidator Class

- Introduced at 9.3
- A Python class that you program
- Allows full control of dialog
  - Better UI, validating relationships between parameters, messaging
- Allows you to fully describe outputs for chaining in ModelBuilder
  - Through the use of a schema object
  - This is where you define the schema (fields, etc) of derived outputs
Tool Validator Class

- **initializeParameters()** – whenever a tool’s signature is requested

- **updateParameters()** – called whenever a parameter value is changed

- **updateMessages()** – called after updateParameters()
Demo: controlling the UI
Demo review -- Basic ToolValidator

- The basics of editing a ToolValidator class
- Setting up keyword lists, categories
- Dynamic update of keyword lists
  - Keyword list changes based on values in another parameter
  - (The kind of stuff basic validation cannot do)
- See documentation – Customizing script tool behavior
Internal validation — called after updateParameters()

1. If a required parameter is empty, post the "Value is required" message to the tool dialog (green dot)
2. Check that the value the user entered is of the right type.
3. Check filter membership.
4. Check existence of input datasets
5. Generate a default catalog path for output datasets.
6. Update the description of the output data based on a set of rules contained in a special object called a Schema.
7. Check existence of output datasets against the Overwriteoutputs environment setting.
But wait! There’s more!

9. If the parameter is a Field data type, check that the field exists on the associated table.

10. Check that the output dataset isn't the same as the input dataset (unless the output is derived)

11. For parameters containing linear and areal unit data types, set their default values by examining the corresponding values in ArcMap

12. If the output is a coverage, grid, or INFO table, check the 13 character file name limit for these datasets.
What internal validation doesn’t do

- Update filters based on interaction with other parameters
- Enable/Disable parameters
- Calculate default values
- Perform any tool-specific parameter interaction
- No custom error/warning messages
Parameter states: Altered & HasBeenValidated
Once the user specifies a value for a parameter, it is altered and remains altered forever
  - …unless the user empties (blanks out) the parameter
Once a parameter has been altered by a user, you should never reset its value
parameter.hasBeenValidated

- hasBeenValidated is true if the user has changed the value since the last time updateParameters() was called.
Describing the output

Using the schema object
Describing the output

In ModelBuilder, Add Field updates the description of its output to contain the new field "TrackingID". The Calculate Field tool 'sees' this field, even though Add Field hasn't executed yet.
Describing the output

The Clip tool updates the description of its output data.

- **Name:** E:\data\sample.gdb\buildings_clip
- **Fields:** (same as Buildings)
- **Extent:** (intersection of Buildings and StudyArea)

The Polygon to Raster tool calculates the default cellsize based on the extent calculated by the Clip tool.
Demo – Updating the description of the output

• Tool takes a line feature class and produces a new point feature class containing the endpoints and midpoints of each line

• Output
  - Point feature class
  - All the same attributes as the input
  - Additional field named STATUS with these values:
    - 0 = from point
    - 1 = mid point
    - 2 = end point
  - Roughly the same spatial extent
Demo: updating output schema
Demo review

- Output datasets have a schema object that describes the dataset
- You set up rules on how you want to construct the output dataset description
  - We used fieldsRule = “All”
- Parameter dependencies declare the initial schema of the output
- You apply rules to the schema
  - Feature/Geometry type
  - Extent
  - AdditionalFields
# Schema object methods (rules)

<table>
<thead>
<tr>
<th>Property name</th>
<th>Value(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>String: &quot;Feature&quot;, &quot;Table&quot;, &quot;Raster&quot;, &quot;Container&quot; (for workspaces and feature datasets). (Read-only property.)</td>
</tr>
<tr>
<td>clone</td>
<td>Boolean</td>
</tr>
<tr>
<td>featureTypeRule</td>
<td>String: &quot;AsSpecified&quot;, &quot;FirstDependency&quot;</td>
</tr>
<tr>
<td>featureType</td>
<td>String: &quot;Simple&quot;, &quot;Annotation&quot;, &quot;Dimension&quot;</td>
</tr>
<tr>
<td>geometryTypeRule</td>
<td>String: &quot;Unknown&quot;, &quot;FirstDependency&quot;, &quot;Min&quot;, &quot;Max&quot;, &quot;AsSpecified&quot;</td>
</tr>
<tr>
<td>geometryType</td>
<td>String: &quot;Point&quot;, &quot;Multipoint&quot;, &quot;Polyline&quot;, &quot;Polygon&quot;</td>
</tr>
<tr>
<td>extentRule</td>
<td>String: &quot;AsSpecified&quot;, &quot;FirstDependency&quot;, &quot;Intersection&quot;, &quot;Union&quot;, &quot;Environment&quot;</td>
</tr>
<tr>
<td>extent</td>
<td>Extent object</td>
</tr>
<tr>
<td>fieldsRule</td>
<td>String: &quot;None&quot;, &quot;FirstDependency&quot;, &quot;FirstDependencyFIDsOnly&quot;, &quot;All&quot;, &quot;AllNoFIDs&quot;, &quot;AllFIDsOnly&quot;</td>
</tr>
<tr>
<td>additionalFields</td>
<td>Python list of field objects</td>
</tr>
<tr>
<td>cellSizeRule</td>
<td>String: &quot;AsSpecified&quot;, &quot;FirstDependency&quot;, &quot;Min&quot;, &quot;Max&quot;, &quot;Environment&quot;</td>
</tr>
<tr>
<td>cellsize</td>
<td>double</td>
</tr>
<tr>
<td>rasterRule</td>
<td>String: &quot;FirstDependency&quot;, &quot;Min&quot;, &quot;Max&quot;, &quot;Integer&quot;, &quot;Float&quot;</td>
</tr>
<tr>
<td>rasterFormatRule</td>
<td>String: &quot;Img&quot;, &quot;Grid&quot;</td>
</tr>
<tr>
<td>additionalChildren</td>
<td>Python list of datasets to add to a workspace schema.</td>
</tr>
</tbody>
</table>
The validation flow of control is as follows:

1. When the tool dialog is first opened, initializeParameters() is called. You set up the static rules (rules that don't change based on user input) for describing the output. No output description is created at this time since the user hasn't specified values for any of the parameters (unless you've provided default values).

2. Once the user interacts with the tool dialog in any way, updateParameters() is called.
   - updateParameters() modifies the schema object to account for properties that can't be determined from the parameter dependencies (such as adding a new field).

3. After returning from updateParameters(), the internal validation routines are called and the rules found in the schema object are applied to update the description of the output data.

4. updateMessages() is then called. No changes to the schema can be made here (output description has already been updated).
Tool characteristics

What makes a good tool?
Functional decomposition

- A tool does one elemental operation well
- Use ModelBuilder to sequence tools into a workflow (compose functionality)
A tool must have output

• In order to work in ModelBuilder, a tool MUST HAVE OUTPUT
  - Even if it is just a Boolean pass/fail
  - See, for example, the Delete tool
Tool validation

• A tool validates itself
  - Checks and updates values, repaints UI, messages
  - Uses data elements (descriptions of data) rather than opening datasets
  - Basic validation (w/o using tool validator)
  - Advanced validation (using tool validator)

• A tool describes its output
  - Prior to execution, creates an output data element
  - For ModelBuilder chaining
Parameter naming

• “Input Features” not “Input feature class or layer”
  - “Dataset” means user will browse to disk, not use layer
  - All initial caps

• Label – what shows up in tool dialog (has spaces)

• Name – what shows up in scripting syntax
  - label with underscores instead of spaces
  - You cannot control the name – it’s always the label minus the spaces
Parameter ordering

- Parameter ordering:
  1. Required input datasets
  2. Required output datasets
  3. Required modifiers
  4. Optional inputs
  5. Optional modifiers
  6. Optional outputs
  7. Derived outputs

- Once a tool is released, you cannot insert parameters or change parameter order
  - You can put an optional parameter at the end

- Tools built with ArcObjects can have different ordering for dialog vs. scripting
Keywords

- Keywords should be upper case, no spaces, no special characters other than underscore
  - “INVERSE_DISTANCE”, not “Inverse distance”
  - Keywords are never localized into another language
- Provide default values for keywords and Booleans
Foreground versus Background processing

• Background processing new in 10.0
• Tools running in background have no knowledge of layers that are not tool parameters
• In order for your tool to run in background:
  - All layers used by your tool must be parameters
  - (You can use any dataset or .lyr file because these reside on disk, not in the application like layers in the TOC)
Embedding code

- Once you’ve finished developing your script, you can embed it with the toolbox
  - New at 10.0
  - Right click script tool and select “Import Script…”
  - You can password protect the script so that no one can export it
Debugging script code

For 9.3, see blog post Tips and Tricks – Debugging Python script tools
Adding outputs to map display

- Suppose that within your script you use the Buffer tool
- You want the output of the Buffer tool to be shown in ArcMap
- You will need a script parameter (output parameter) to hold the results of buffer
- If you want the output to be derived (the buffers “auto-magically” appear w/o the user entering the output pathname)
  - Create a derived output parameter
  - In your script, use SetParameterAsText() to set the pathname to the output of buffer
Coming at 10.1 – Python toolboxes

- A Python Class that you implement
- Everything needed is in the class:
  - Tool names, labels
  - isLicensed property
  - Parameter definitions
  - Validation
  - Execution
Session Evaluations

• [www.esri.com/sessionevals](http://www.esri.com/sessionevals)
Questions?