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Technical Workshops | ******************

An Introduction to Dynamic Simulation Modeling

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Outline

- Model types
  - Descriptive versus process
    - Phenomenon, error analysis, and sensitivity analysis
  - Static versus dynamic
  - Deterministic versus stochastic
- Modeling techniques for adding time
- Demonstrations
    - Simple fire model – dynamic modeling introduction
    - Complex fire model - stochastic events
    - Flood model – a model in a model
    - Chemical spill – Iterators

The problem

- I have been modeling phenomenon as static events or have been generalizing time in the modeling process
- In my particular case, the phenomenon is reactive to what is occurring around it each time step
- I want to try to model time more explicitly

Context - Types of models

Model Types

Descriptive

Based on the attributes at a particular location you assign weights and preferences. You describe or quantify what is there.

Example - A housing suitability model

Process

Describes a physical process.

This is not to be confused with a ModelBuilder process.

Example - Hydrologic model of current conditions.

What do you model?

1. - The actual <u>physical event</u> or phenomenon
    - Predict how the fire will grow or a chemical will spread
2. - The <u>error</u> inherent in the input and in the processing
    - In the input data
        - Measurement
        - Local variation
        - Outdated information
    - In the parameters
    - In the processes of the modeling tools
    - In the assumptions

    <u>Addressing error:</u>

    - With *priori* knowledge of the error distribution
    - Error propagation or scenarios

Cont….What do you model?

3 • Perform sensitivity analysis
  - Understand the interaction of the parameters – no randomness
  - Systematically change one parameter (or input) to see how output changes
  - Small change causes big change in output, model sensitive to the parameter
  - Robust if the results do not change much

Context - Types of process models

Based on the conditions for a specified time interval; a <u>slice of time</u>.

Event:
Define a stream network
Error:
Change the channel roughness coefficient in a hydrologic model
Sensitivity:
Change the threshold for a stream network model

<u>Time is explicit</u>. The output from one time interval is feed as the input to the next time step.

Event:
Wildfire growth model
Error:
Vary the DEM (affecting slope) for each model run for wildfire growth
Sensitivity:
Systematically change a wind speed parameter in wildfire model

Context - Types of process models

Process

Deterministic

The precise <u>outcome can be predicted</u> because full knowledge of the process and its relationships is understood.

Event:
Wildfire growth model
Error:
Alter income layer in housing suitability
Sensitivity:
Change weight for distance to road for suitability model

Stochastic

Events appear <u>random</u>. Random or you do not have complete information and understanding?

Results are probabilities.

Event:
Parameter:
Wildfire with spotting
Error:
Randomly add error to DEM in a stream network model

Putting it together

			Model Type		Modeling Technique	
			Descriptive	Process	Error	Sensitivity
Deterministic	Static		Housing suitability model	Hydrologic model of current conditions	Housing suitability, change input income layer	Housing suitability, change parameters
Deterministic	Dynamic		NA	Wildfire growth model	Alter fuel load in a wildfire model	Run wildfire growth model and systematically change multiple parameters
Stochastic	Static	Input	NA	NA	Alter the DEM within a hydrologic model	Alter the precipitation input used in a hydrologic model
Stochastic	Static	Parameters	NA	Changing the stream threshold value using a random value within a hydrologic model	Vary parameters in a hydrologic model (e.g. channel roughness coefficient)	Vary parameters in a housing suitability model (e.g. weights)
Stochastic	Dynamic	Input	NA	Starting condition for animal movement	Vary fuel load for a wildfire growth model	Change a base layer for a wildfire growth model
Stochastic	Dynamic	Parameters	NA	Wildfire growth with spotting (e.g. distance)	Vary parameters in a wildfire growth model (e.g. wind speed)	Systematically change multiple parameters of wildfire growth model

How to model time explicitly

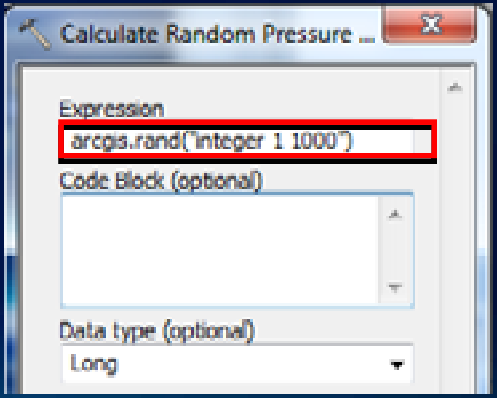
- The length of a time step must be identified
  - The characteristics of the phenomenon
  - What you know of the phenomenon
  - The resolution of the data
  - Model in a model
- A set of general movement rules must be defined that can be applied to the phenomenon each time step
- The rules must be applied to the phenomenon each time step - iterators
- Different responses might occur depending on the status of the phenomenon – branching and merging

How to model time explicitly

- The status of the landscape may change each time step – feedback looping
- Multiple output will be created – inline variable substitution
- Since you cannot precisely model every move or decision each time step some randomness must be used – random

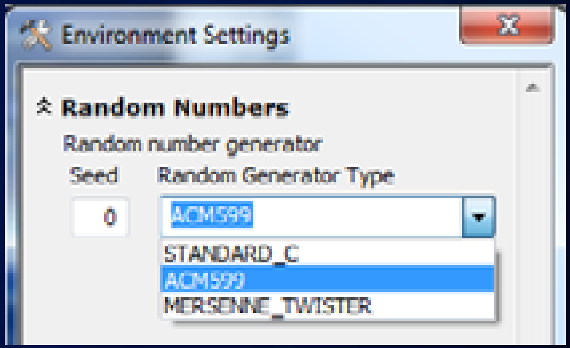
Random number generation

- Need to create random numbers - Calculate Value tool
  - *Example*: CalculateValue("arcgis.Rand('integer 1 1000')")
- A number of distributions are supported
  - UNIFORM {minimum}, {maximum}
  - INTEGER {minimum}, {maximum}
  - NORMAL {mean}, {standard deviation}
  - EXPONENTIAL {mean}
  - POISSON {mean}
  - GAMMA {alpha}, {beta}
  - BINOMIAL {N}, {probability}
  - GEOMETRIC {probability}
  - PASCAL {N}, {probability}



More on random number generation

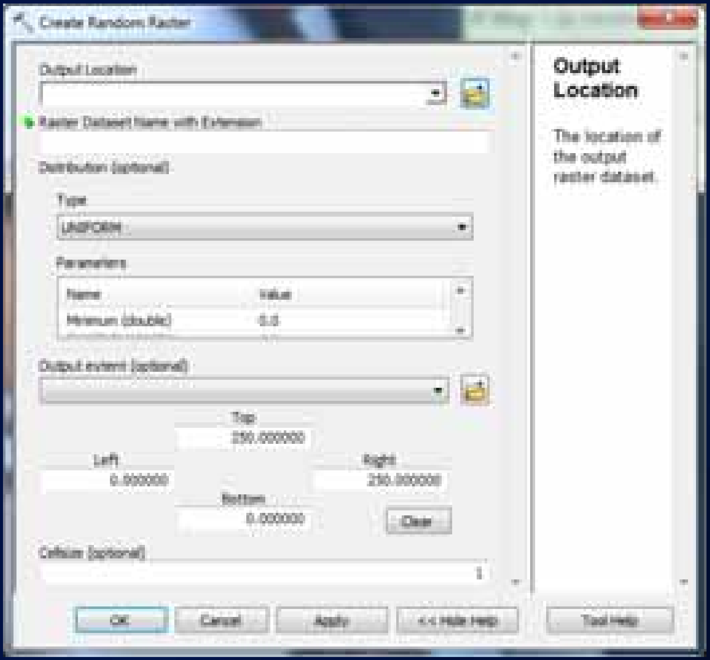
- Need to reproduce the random results – **seed**
- The seed value that is used by the random function comes from a Random Number Generator environment setting
- Three generator types are supported
  - Standard C Rand() function
  - ACM collected algorithm 599
  - Mersenne Twister mt19937



- Settings may be specifically set for each process
  - Supports global vs. local streams

More on random number generation

- Need to create a raster with random values with a given cell size and within a given extent - **Create Random Raster**
- Provides the same distribution options supported by the ArcGIS rand function



Random points and assigning random values

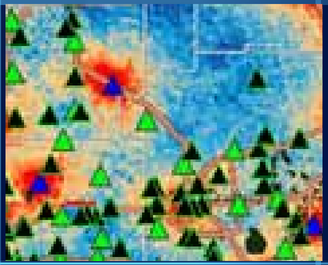
- Need to randomly place a specified number of points in a new feature class. Points may be placed within one or more constraining polygons - Create Random Points
  - Starting points for a simulation
  - Replicate the spread of a phenomenon (e.g. from air born)

- Need to be able to create random values for fields - Calculate Field
  - CalculateField sample.shp value “arcgis.rand(‘Normal,0,10’)”

Demo 1: Fire Model (Conceptual)

Iteration

Feedback



Fire model characteristics

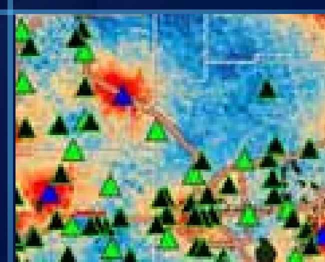
- Move all or nothing based on a series of criteria
- Environmental factors
  - Wind speed, wind direction, rain, and temperature
- Characteristics of the fire
  - Temperature of the fire
- Characteristics of the landscape
  - Fuel load, aspect, slope
- Output of one time step is the input to the next time step
- Many aspects are not fully understood
  - Wind, temperature, spotting

Demo 1 - Recap

- Introduction to dynamic model creation
- Change the paradigm – you can not change another cell value
- Iterators
- Feedback
- Specification of time – through the rule set
- Displaying the results - animations

Demo 2: Fire Model (Realistic)

- Iteration
- Feedback
- Condition
- Branching



Demo 2 - Recap

- Adding complexity to capture actual interaction
- Additional insight to iterators and feedback loops
- Stochastic events through random numbers
- Conditions and branches

Demo 3: Flood (Complex)

Raster/Vector integration

Model in a model

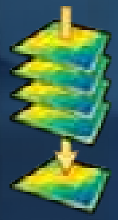
Demo 3 - Recap

- Explores time through rule sets
- Model in a model
- Expands capability beyond ArcGIS to fulfill application requirements
- Multiple animations

Demo 4: Oil Spill (Complex)

Integration of Iterators

Multiple interactions



Demo 4 - Recap

- **Realism through nesting models**
- **Control time through Iterators**
- **Raster/Vector interaction**

Tips on planning a dynamic model

- What application?
- What do you want to find?
- What parameters affect the model?
- What data do you have?
- Does the model require iteration? Iterating what?
- What do you know about the phenomena?
- What is the time step for the model?
- How do you want to display the results?
  - Batch process
  - Graphs
  - Animations

Summary

- Descriptive models
  - Rich set of tools
- Process; event, error analysis, and sensitivity analysis models
- Static or dynamic
- Supporting tools in the Geoprocessing/ModelBuilder framework
  - Incorporate time and iterate (looping)
  - Add randomness (random values to input data; random variables to parameters; randomness to model events)
  - Capability to analyze multiple representations
  - Visualization and exploration tools

Cont….Summary

- Results in better decision making
- Future questions
  - How do we work with <u>probability surfaces</u>?
  - Tools to quantify the difference between realizations
  - Model <u>time explicitly</u> not implicitly
  - Spatially autocorrelated and cross correlated random values
- Finding additional information
  - Online help

Open to Questions

…Thank You!

Please fill the evaluation form.