Spatial Modeling and Programming

The slides about GIS modeling in this lecture are prepared by Dr. Michael W. Binford, U of Florida
Spatial Modeling

- Cartographic Model (static)

- Spatial-temporal Model (dynamic)
  - Cell-based model (cellular automata, CA)
  - Agent-based model

“Designing the best cartographic model to solve a problem – the selection of the appropriate spatial tools and the specification of their sequence – is perhaps the most important and often the most difficult process in cartographic modeling.”
Definition of “Model”

• Simplified, idealized representation of a part of the real world
• Learning Tool
• Experimental Tool
• Constantly tested by comparison with the real world
• Useful insofar as they explain or simulate the real world

Models come in many, many flavors.

• **Analysis Models** – Step-by-step description of how problems are solved.
• **Representation models** – images, dioramas, wind-tunnel models, flow channels, sand tables, maps, globes.
• **Conceptual models** - no numerical values or formulas
• **Theoretical models** - with numerical values or formula
• **Empirical models** - based on observations, but the mechanism may be unknown.
  • Statistical, e.g. Regression Models
  • Rule-based Models
  • Models based on many measurements (e.g. USLE, RUSLE)
• **Physical-mathematical models** - based on physical laws, first principles
• **Stochastic models** - bases on the concept of randomness and probability: Random numbers simulate variation.
Representation Models

Representation Models in GIS

Digital Elevation Model
GIS Modeling

- Representation Modeling
- Exploratory Data Analysis
- Environmental Modeling
  - Environmental Risk Assessment
  - Atmospheric Modeling
  - Soil Erosion Modeling
  - Hydrological
    - Topographic Modeling
    - Watershed Analysis
    - Dynamic Modeling
  - Land-water interactions
  - Habitat Modeling
- Human-Environment Modeling
  - Land Suitability Modeling
  - Land-use/land-cover change
    - Economic models (Walker)
    - Agent-based models
- Archaeological Modeling
- Decision-Support Systems
  - Land allocation
  - Agroforestry (Ellis)
- Business/Economic Modeling – Thrall
- Emergency Management

Different Models for Different Questions

1. Define Problem
2. Recognize Context
3. Define Time

- Landscape Description
  - Data
  - Information
  - Cultural Knowledge
  - Define Problem
    - Recognize Context
    - Define Time
  - Representation Models
  - Process Models
  - Evaluation Models
  - Change Models
  - Impact Models
  - Decision Models

Steinitz et al. 1996
Analytical Models: Project Design With Cartographic Modeling

- **Cartographic Modeling (= Spatial Modeling)**
- **Models (representations) using Maps (Cartography)**
- Analytical model based on simple, sequential operations.
- Start: “What is the Question? What are the Objectives?”

**Principles of Cartographic Modeling**

1. Cartographic Modeling emphasizes process, not data specifics. (Should accommodate new/changed data.)
2. Cartographic Modeling decomposes analytical tasks into elementary components that can be combined into complicated algorithms.
3. Cartographic modeling is useful for making the work flow more efficient.
4. Every object class (data, operation, map, etc.) has a specific symbol.
5. Useful flowcharts (Cartographic Models) should contain enough information for both you and someone else to reproduce the analysis.
Cartographic Modeling: Methods of Flowcharting

• After the question and objectives are adequately defined, **Determine the output product FIRST.**
  • What are the final maps, tables, graphs that you need to determine and support the conclusions of your study?

• Break up the task into smaller sub-tasks by working backwards from the final result.

• **Define how you will combine variables and operations to achieve the final maps, tables, graphs, etc.**

• Isolate each element (data, map, intermediate result, operation) that will be used in the model.

• **Determine the input data.**
  • What do you have/need to solve a specific problem?

A note about cartographic modeling

• **Qualitative statements** (“too steep,” “big enough,” “far away”) must be made quantitative. (GIS generally not good at fuzzy.)

• **Consultation, meetings, discussions, etc., with “client group” may be necessary.**
Terrible Cartographic Model

Get Data → Analyze Data → Present Table of Results

Say What???

Examples of Spatial Models for Problem Solving

• Environmental Impact of a new Road
Problem 1

- **Problem:** A new road is going to be built between cities A and B, through a forest with both high biodiversity and high development potential.

- **Question:** How much undisturbed forest is going to be affected?

- **Principle:** New roads affect a zone 2 km wide on each side of the road
  - Sound
  - Territorial Birds
  - Water and Sediment Runoff

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### Affected land Area m²

<table>
<thead>
<tr>
<th></th>
<th>Area m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Forest</td>
<td>345453</td>
</tr>
<tr>
<td>Disturbed Area</td>
<td>76755</td>
</tr>
</tbody>
</table>

---

**What do we want at the end?**

- **Output Data**
  - Table with the area of affected lands

**How do we get from here to here?**

- **Input data**
  - Land Use/Cover Map
  - Proposed New road
Problem 1

• Can you come up with a flowchart for answering this specific problem?

• Possible Solution with Operations Available:
  • Buffer
  • Reclass
  • Overlay (Intersection)

Problem 1

• This problem can be solved with the procedure described in this flowchart
Problem 2: Universal Soil Loss Equation, USLE

• In a given region, what are the areas with the largest soil losses? What are the magnitudes of the losses?
• The USDA (Dept of Agriculture) has developed an empirical equation for estimating soil erosion (Universal Soil Loss Equation).

\[ A = R \times K \times L \times S \times C \times P \]

R=Erosivity or Rainfall
K=Soil characteristics
L=Length of the slope (topographic)
S=Slope (topographic)
C=Type of cultivation
P=Protection parameter (i.e terraces)

Problem 2

• Output Data:
  Map showing the areas with the largest soil erosion losses

• Input Data
  Rainfall, Soils, Topographic Map, Land Use (Agriculture)
Problem 2

• Operations available
  • Arithmetic (x, +, -, /)
  • Reclass or Recode
  • Slope and Length of Slope (Topographic)
  • Greater Than, less than

• Can you create a flowchart for solving this problem?
Example: Suitability Analysis

For a park: Near lakes, near roads, not wetlands


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Example: Home Site Selection

<table>
<thead>
<tr>
<th>General Criteria</th>
<th>Refined (Quantified) Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slopes not too steep</td>
<td>Slopes &lt; 30 degrees</td>
</tr>
<tr>
<td>Southern aspect preferred</td>
<td>90 &lt; aspect &lt; 270 degrees</td>
</tr>
<tr>
<td>Soils suitable for septic system</td>
<td>Specified list of septic-suitable soils</td>
</tr>
<tr>
<td>Away from major roads, but not isolated</td>
<td>300m &lt; distance to road &lt; 2000m</td>
</tr>
</tbody>
</table>
Available data

Raster

Meet criteria? Assign codes for yes or no.

Add, to ID areas of good slope & aspect by sum

Suitable or unsuitable

Simplify

Not helpful to say “overlay”!

Suitable or unsuitable

Simplify

Intersect, to map areas of suitable terrain AND soil
Project Management: Flowcharting

- The major objective of a flowchart is to communicate the operations and their order to yourself as well as to someone else.
- Every object class (data, operation, map, etc.) has a specific symbol (e.g., in MS Office).

Data - map

Process - operation

Statistical Table

Multiple Data Layers?

Decision

\( x > y \)

Yes

No

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Points about Cartographic Modeling

- Cartographic Modeling comprises simple objects and operations; however, combining objects and operations in specific sequences becomes complicated.
- Begin at the end: What do we want? (Did I say this already?)
- Cartographic model, or flowchart, must be sufficiently comprehensive to inform the analyst and the audience.
- Another analyst should be able to reproduce your project by reading your flowchart. “Reproducible” = “defensible.” These are essential to good science.
- Criteria: opportunity for expert and public input to modeling!

Kinds of Model – GIS Links

1. No GIS at all, but model is spatially explicit
2. GIS holds data, model is not spatially explicit but takes as input aggregated information calculated by GIS.
3. GIS holds data, model is not spatially explicit but runs within GIS.
4. GIS holds data, model is spatially explicit but runs outside GIS.
5. Model is integrated with GIS software.
Modeling – Taxonomy of Models

GIS modeling Wrap-Up

- Spatial Modeling is infinitely diverse – limited only by your imagination.
- Not limited to functions already within GIS application software (ArcGIS, etc.)
- But, developing models outside of GIS software programs requires programming knowledge: Java, Python, Fortran, C++, VisualBasic, or any other. LEARN AT LEAST ONE PROGRAMMING LANGUAGE.
- What is your interest?
Second Part

GIS Programming

Why GIS Programming?

- To calculate values needed for analysis
- To perform repetitive tasks
- To created customized GIS interface for special purposes
- To automated complex GIS modeling
Example of Tasks

- Reproject 1000 shape files from Lon/Lat to UTM coordinates
- Build a simplified map interface for using by land manager with customized features
- Simulate flood progress when a certain event is happened.
- Include a map in an EXCEL spreadsheet

Why do you need to learn GIS Programming?

- For Research:
  - Dynamic spatial modeling
  - Repeated, intensive computing
- For Career:
  - More easily to get a job
  - More easily to get more $$

GIS Job Cleanhouse: http://www.gjc.org
GIS Programming Languages: ESRI Products Suites

• ARC/INFO: Arc Macro Language (AML): too old
  • Essentially a list of normal ARC commands
  • Some features for variables, looping etc.
  • Used only in Arc/INFO

• ArcView (through V3.3) AVENUE language: too old
  • Object-oriented Programming
  • Used only in ARCView

• ArcGIS: ArcObjects: that’s right now, but it will be too old!
  • COM complaint (Component Object Model), interface for software components, introduced by Microsoft in 1993, language neutral
  • Whatever COM-compatible language: Virtual Basic, Virtual Basic for Application, Python, C++, JAVA, .NET etc.
  • ArcGIS Engine and ArcGIS Server

ArcGIS Engine and ArcGIS Server

• Media Clip: introduction to ArcGIS Engine
  [Link](http://gis.esri.com/esriclips/clip.cfm?ClipID=213)

• Introduction to ArcGIS Server:
  [Link](http://esri.com/software/arcgis/arcgisserver/about/demos.html)
Common themes in various programming languages

• (Chinese vs English) VS (C++ vs C#):
  • the most important thing is the logical, rather than characters

• Common themes:
  • Primitives (string name=“GIS”)
  • Control Flow (if, else, else if, then)
  • Loops (count, condition or collection)
  • Sub routine/function (private function doSth())

Fundamentals of ArcObjects

• Object Oriented Programming (OOP)
  is a programming paradigm that represents the concept of "objects" that have data fields (attributes that describe the object) and associated procedures known as methods.

• Component Object Model (COM)
  language agnostic

• Objects vs. Classes
  Class is a construct that defines a collection of properties and methods
  Object is an instance of a class, it brings it to “life”

• Object Model Diagram
Benefits for using ArcObjects

• There are a large number of objects defined by ESRI which can control all aspects of ArcGIS applications

• Only requires you to know what the objects are and what methods and properties are available to you

• You can use any COM-compatible language
  Python is really popular these days!

• The objects allow you to do EVERYTHING you can do in ARCGIS and more!

Challenge of using ArcObjects

• Some basic understanding of OOP language such as Visual Basic or Python is expected

• The large (huge?) number of objects available makes it difficult to locate the object or method you need
Object Model Diagram
ArcObjects in ArcMap

How to go about learning ArcObjects

• First go through a basic Visual Basic or Python book
• Think of a task that you want to tackle
• Find sample code that does something like what you are looking for
• Develop code snippets that work, then try to put them together
Places to find help

- Online Developers web site
- ArcObjects Developer Help
- Object Models
- Components/Core Components/Interfaces
- Sample Code
- Ask Google before asking anybody

Pain and Gain?
Thank you and Best wishes to you!

• Thank you for your participation in this GIS course!

• Wish you success with the skills learnt from this course!