GIS & Spatial Modeling

Class 2: „Spatial Doing“ - A discourse about analysis and modeling in a spatial context
Updates

• Class homepage at:
  http://www.colorado.edu/geography/class_homepages/geog_4203_s08/

• Handouts online (step by step)

• Some PDFs for readings discussions can already be downloaded

• Reminder for readings topics pick up (next week: fields vs. objects)

• Statistics and GIS levels
The GIS Levels at Geog ...

- **GIS 1**: Fundamentals of GIS, data structures and operations
- **GIS 2**: GIS modeling, raster based approaches, concepts and techniques of modeling for complex spatial problems
- **GIS 3**: GIS programming, developing and implementing new functionality and methods for GIS and spatial modeling
- Overlap / transition / prerequisites definition
Last Lecture

• You obtained some ideas of what this course is about and what you can expect from classes and exercises
• You have seen how broad the range of topics will be - so we have a lot to do
• You have an impression of the rules, don’ts and do’s for this course
Today‘s Outline

• We will look closer at some important terms such as **spatial (data) analysis** or **spatial modeling** and will talk about different taxonomies

• We will see some **examples** to clarify how to use spatial analysis

• How can we better **understand** these terms and what are the central issues of spatial analysis and spatial modeling?
Learning Objectives

• Conceptually understand important **key terms** and considerations
• Understand why many different **classifications and definitions** exist and what the common sense between them is
• Getting a sense for how we can **explore terminology** that comes with an ambiguous flavor of meaning
Introduction

• In GIS 2 we will talk a lot about **spatial modeling** and **spatial analysis**
• … and this is what we do when working with the GIS toolsets
• Before going into any detail we need to know how to understand these umbrella terms
Finding the Beginning...

Let’s try to approach something like an understanding of what is …
- … spatial analysis? Or even spatial data analysis?
- … spatial modeling?

- Does it help to define/classify them?
- Or does it make more sense just to understand what we are doing?
- Here a first historical example…
The Broad Street Pump

- Cholera outbreak in Soho / London, England 1854
- Dr. Snow and his theory of contaminated water in wells
- Monitored the epidemic by interviews
- Leads to the pump at Broad Street
- Removal of the handle saved an unknown number of live
- Find more at: http://www.ph.ucla.edu/epi/snow.html
Snow mapped the monitored cases and could determine the location of the well closest to these cases.

This was genius-like!

Snow as the pioneer of modern epidemiology which uses spatial analysis to a high degree.
Defining Spatial Analysis?

- *Longley et al. 2005:* Spatial analysis is a set of methods whose results change when the locations of the objects being analyzed change.
- Perspective: **Analytical toolset that takes into account the spatial frame**
Defining Spatial Analysis?

- **Goodchild, 1988**: “The true value of GIS lies in their ability to analyze spatial data using the techniques of spatial analysis. Spatial analysis provides the value-added products from existing datasets”
- **Perspective**: ‘Gaining’ valuable products from spatial data?
Defining Spatial Analysis?

- *Goodchild (et al.) 1987/1992:* (SDA) is a set of techniques devised to support a **spatial perspective** on data. To distinguish it from other forms of analysis, it might be defined as a set of techniques whose results are dependent on the **locations** of the objects or events being analyzed, requiring access to both the **locations** and the **attributes** of objects.

- **Perspective:**
  Techniques using Locational and attribute information
Defining Spatial Analysis?

- **Haining 1994**: [SDA]... is a body of methods and techniques for analyzing ‘events’ at a variety of spatial scales, the results of which depend upon the spatial arrangement of the ‘events’.
- **Perspective**: Techniques that address scale and spatial patterns?
Defining Spatial Analysis?

• We stop here! You will find many other definitions in different contexts - but how much do they help?

• Altogether we might say: Spatial analysis has something to do with deriving information from data using the spatial context of the problem and the data (e.g. their distributions or patterns)

• It is exactly this - space - which makes it different

• Maybe we understand more if we look at some taxonomies of operators for spatial analysis such as…
... Based on Classes of Techniques

- Longley et al. 2001: Tried to classify relevant techniques of spatial analysis based on conceptual frameworks
  - simple queries, which return results already existing in the database;
  - measurements, which return measures of such properties as distance, length, area, or shape;
  - transformations, which create new features from existing features;
  - descriptive summaries, which compute summary statistics for entire collections of features;
  - optimization, which results in designs that achieve user-defined objectives, such as the search for an optimum location; and
  - hypothesis testing in which statistical methods are used to reason from a sample to a larger population.

- Perspective: Analytical toolset for querying, measuring, transforming, describing, optimizing and hypothesis-testing
... Based on Conceptual Models

- *Burrough and McDonnell 1998:* Divide spatial operations in two different categories - depending on the **conceptual model** (which was not only successful)

- **Entities:** Attribute operations, Distance/location operations, Operations using built-in spatial topology

- **Fields:** Interpolation, Terrain analysis, Spatial filtering, etc.
Based on the Data Model

- **Tomlin 1990:**
  - made efforts to **codify** analysis (map algebra for rasters)
  - identified four basic classes of **operations**
  - defined an associated language termed **cartographic modeling** (basis for command syntax in many GIS packages)
Does it help?

• As you can see there are (as expected) many different approaches to build a taxonomy
• You have seen three of them: one based on category of technique, one based on the conceptual model and one based on the data model used
• What most of them have in common is: They include most of the (functional) operations in a GIS, somehow
• Let’s look at some examples
Example 1: Exploring & Describing

- **Fire scares** in forests
- Total portion of **burned area, classes**
- Mean and median size of patches & std. deviation of patch size
- **Shape (compactness) of patches** (circularity: \( M = 4\pi \times \text{area} / \text{perim}^2 \))
- Comparing **burned** with **non-burnt** areas
- Comparison with properties of other gaps/patches (harvested or blow-down)
- **Distance** to other burnt patches
Example 2: Explaining the Occurrence

- Trying to **explain** the occurrence of forest fires by **analyzing** and **exploring** the available **data**
- **Formulating Hypotheses** (fuel, climatic conditions, land use, traffic) and **data** needed…
- **Sampling** (autocorrelation)
- **Significant** variables for **regression** analysis?
- **Evaluation** of ‘predictions’
Example 3: Criteria-Based Planning

- Suitability analysis
- Criteria (what means)
- Quantification (how to)
- Overlay
- Function formulation
So maybe it’s rather: How to use SA?

• The three examples gave you an impression in which contexts SA can be used (and this comes along with Openshaw and Goodchild & Longley in Longley et al. 2005)

• Explore / describe spatial patterns and relationships (exploratory/descriptive approach)

• Testing hypotheses regarding spatial patterns and relationships (explanatory/confirmatory approach)

• Simple analysis for criteria evaluation
So what about Spatial Modeling …?

• ‘Modeling’ per se is one of the most overloaded terms anywhere
• Reason enough to think about what exactly we think of by referring to spatial modeling
• Generally, a model is a (simplified) description of reality (static reproduction, conceptual description)
• Modeling can (or should) be considered as a process …
Modeling Process and its Components

Prior to carrying out the modeling process it is helpful to find answers to four questions (DeMers 1,5):

- **What is the model to tell us** (explaining, predicting relationships or consequences / evaluating situations for resource uses,...)? Or simply: Do we understand what the problem is?
- **What type of data do I need**?
- **How to create a design to put the model together**?
- **How to apply existing tools**, carefully and appropriately to derive **meaningful** models?
- Validation and verification as important steps are touched later
What is GIS Modeling?

- GIS Modeling is a **PROCESS**
- Need of a way to “think spatially”
- How to represent (abstract) our world in a GIS?
- What are the **visible** or **functional** patterns
- What are the **spatial relationships** between representations in the geographic space?
- What can these relationships tell us and how can we combine/measure/examine them to derive **meaningful models**?
- As always, a **structure** is helpful!!
What is a Spatial Model

- **Spatial models** (at some places GIS models) might describe basic properties and processes for a set of spatial features (*Bolstad 13 - you have heard about this*)
- The aim is to study **spatial objects or phenomena** in the real world
- As you can imagine we also find dozens of definitions and many different classification schemes - we will look at **three of them**
Spatial and GIS Models I

(Bolstad)

- **Cartographic models:**
  temporally static, combined spatial datasets, operations and functions for problem-solving

- **Spatio-temporal models**
  dynamics in space and time, time-driven processes

- **Network models:**
  modeling of resources (flow, accumulation) as limited to networks
Cartographic Models

- Ranking and Weighting of criteria
Spatio-temporal Models

Spatial and temporally dependent functions

Spatial output
Spatial and GIS Models II

(Goodchild 2003)

• **Data models:**
  Entities and fields as conceptual models

• **Static modeling:**
  taking inputs to transform them into outputs using sets of tools and functions

• **Dynamic modeling:**
  iterative, sets of initial conditions, apply transformations to obtain a series of predictions at time intervals
Spatial and GIS Models III
(DeMers 2005)

• Based on purpose
  descriptive - passive, description of the study area
  prescriptive - active, imposing best solution

• Based on methodology
  stochastic - based on statistical probabilities
  deterministic - based on known functional linkages and interactions

• Based on logic
  inductive - general models based on ind. data
  deductive - from general to specific using known factors and relationships
What do Spatial Models Do?

- Using spatial data
- Making use of combined **functional capabilities** such as analytical tools for spatial and non-spatial computation, GIS and programming languages
- The focus is on the **meaning** of the model - modeling is more than just applying analytical tools
- Representing **meaningful features, events and processes** in geographical space
Summary

• **Spatial analysis** and **spatial modeling** are two important terms for GIScience
• We tried to explore what stands behind them by looking at **definitions, taxonomies** and **examples**
• However, an understanding of the **methods** we use (exploring / explaining) and of the **problem** we face (modeling) are central
• The aim of **spatial modeling** is to derive a **meaningful** representation of events, occurrences or processes by making use of the power of **spatial analysis**
References