Geography 4203 / 5203

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:

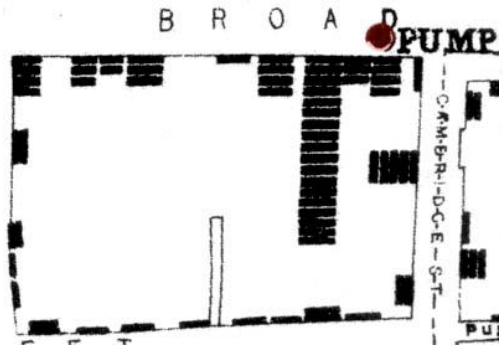
  http://www.ph.ucla.edu/epi/snow.html

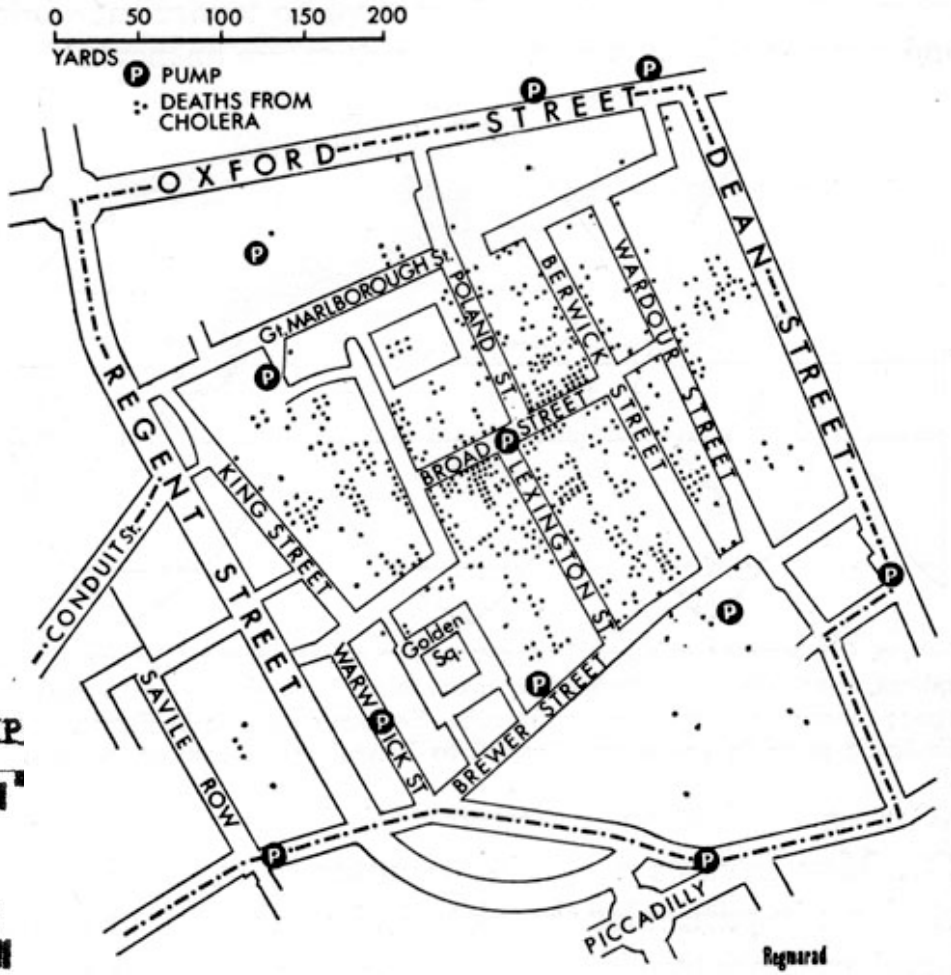
  Or in:

  Tufte, E.R. 1997. *Visual Explanations*

Snow's Map

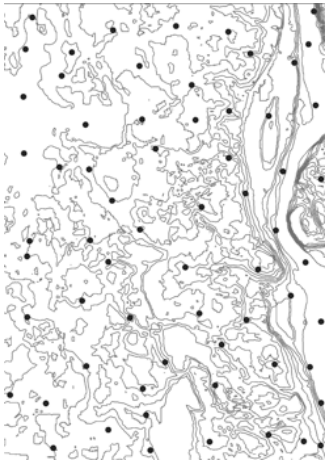
- Snow mapped the monitored cases and could determine the location of the well closest to these cases
- This was genius-like!
- Snow as the pioneer of modern epidemiology which uses spatial analysis to a high degree

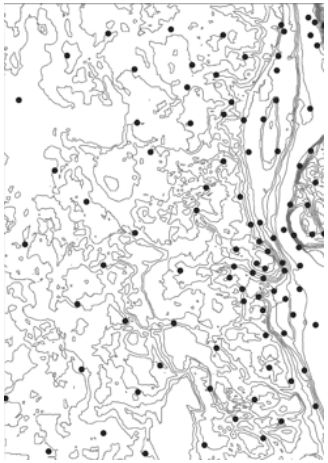




Defining Spatial Analysis?

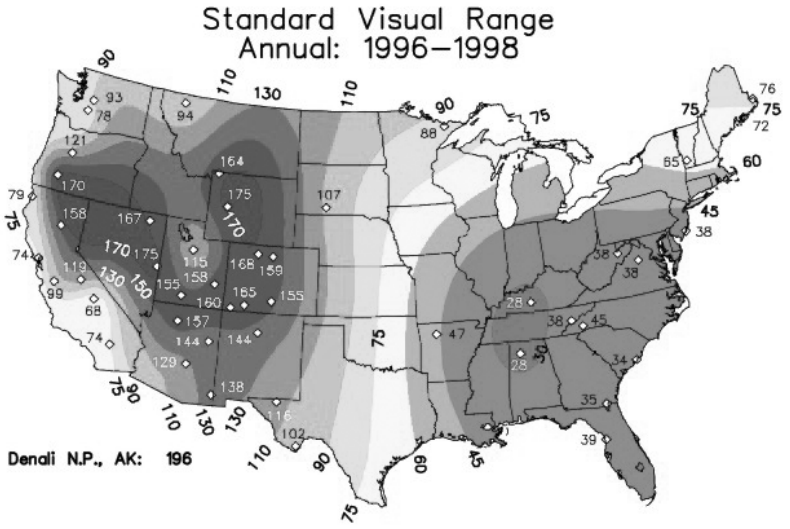
- *Longley et al. 2005:* Spatial analysis is a **set of methods** whose results change when the locations of the objects being analyzed change
- Perspective: **Analytical toolset that takes into account the spatial frame**





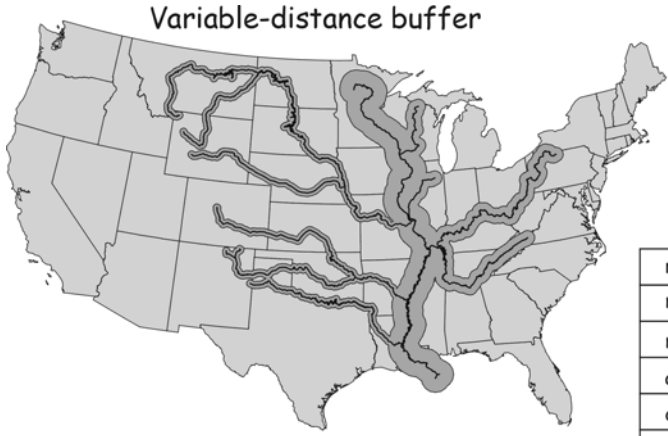
Defining Spatial Analysis?

- *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.

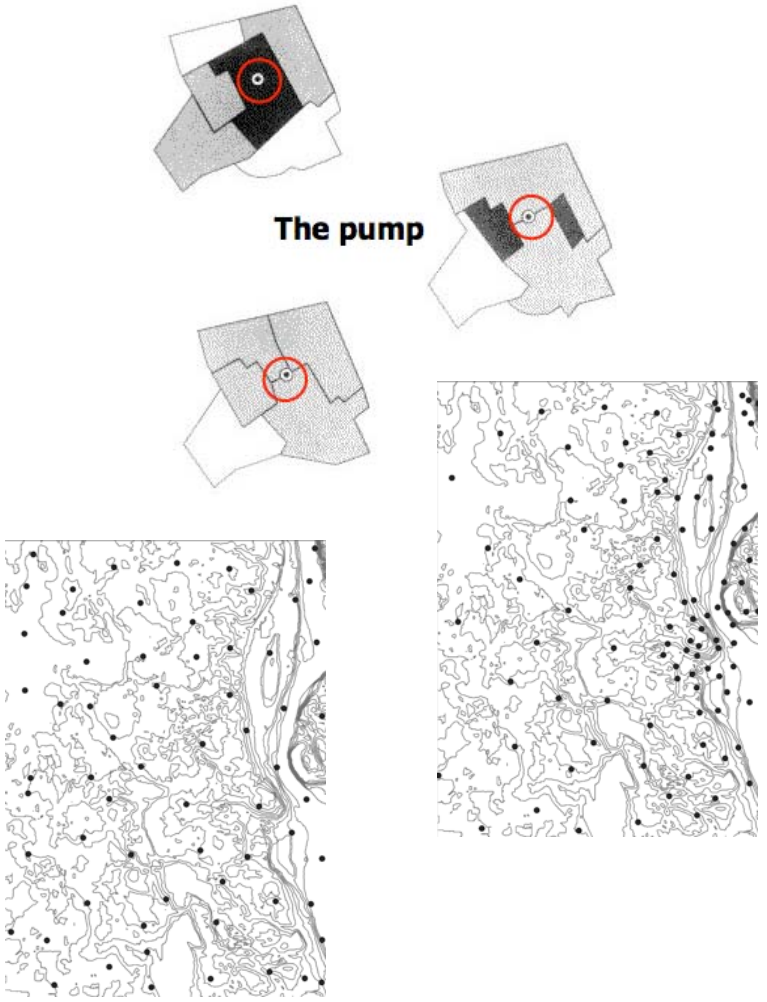


river_identifier	buffdist
mississippi	100
missouri	50
arkansas	50
ohio	75
tennessee	75
st. croix	75
illinois	75
wisconsin	75

- 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

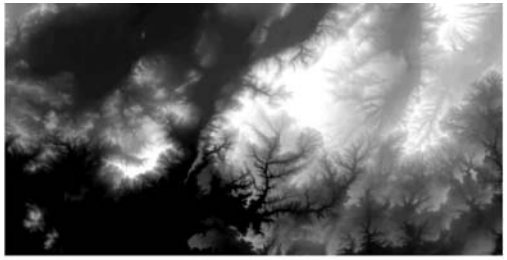
- *Longley et al. 2001:*
  Tried to classify relevant techniques of spatial analysis based on **conceptual frameworks**

- 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
- hypthesis 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.



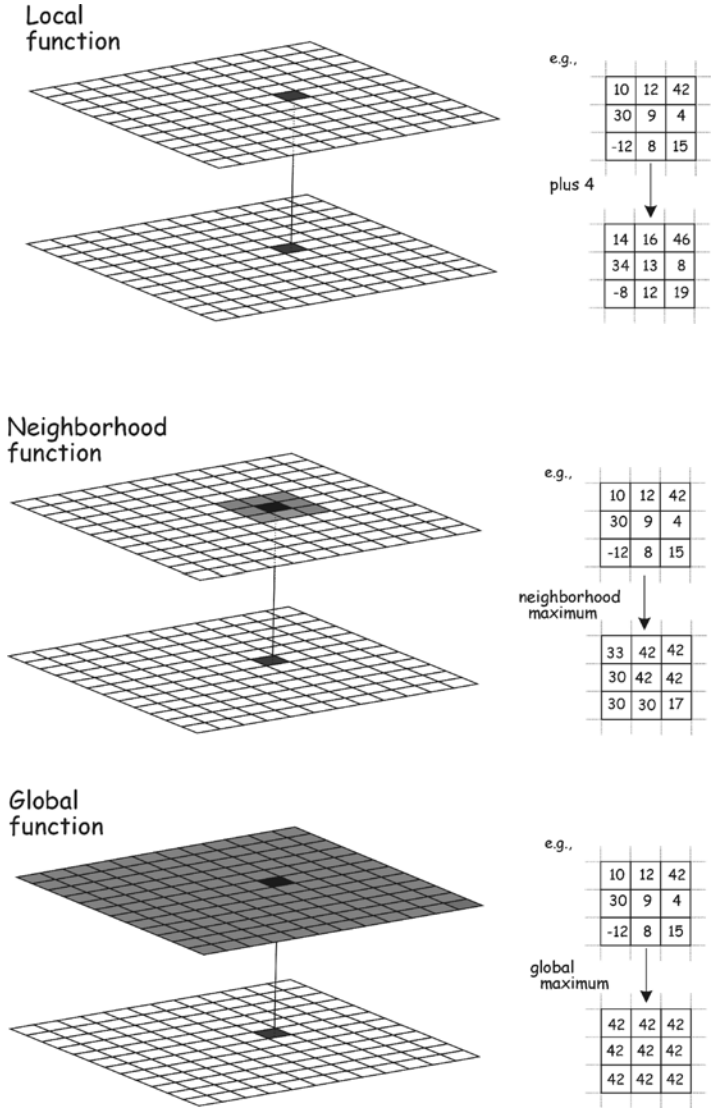
… Based on the Data Model

- *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)

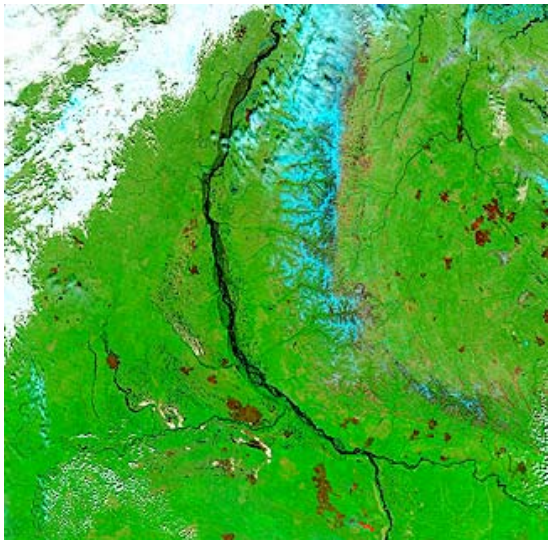


Does it help?

- 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

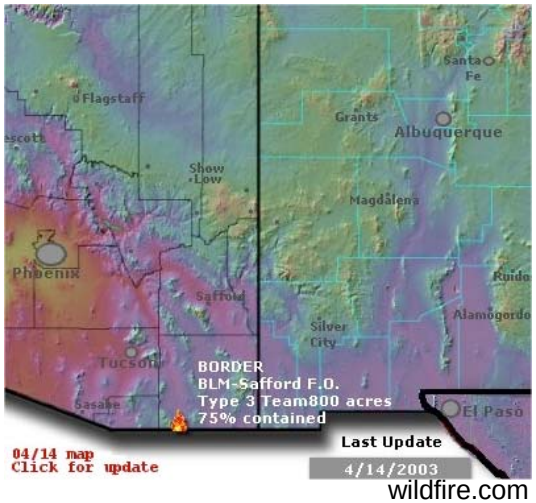
- **Fire scares** in forests
- Total portion of **burned area, classes**
- Mean and median size of patches & std. deviation of patch size
- **Shape (compactness) of patches (circularity: *M = 4π*area / perim²*)**
- Comparing **burned** with **non-burnt** areas
- Comparison with properties of other gaps/patches (harvested or blow-down)
- **Distance** to other burnt patches



University of Freiburg

Example 2: Explaining the Occurrence

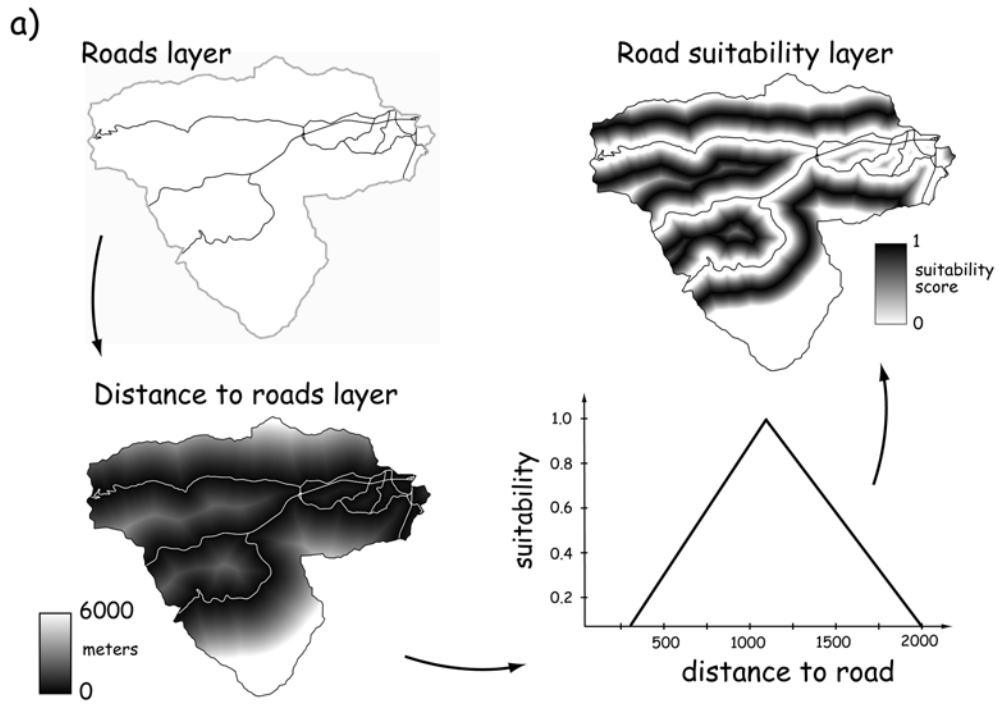
- Trying to **explain** the occurrence of forest fires by **analyzing** and **exploring** the available **data**
- **Formulating Hypotheses** (fuel, climatic condidtions, land use, traffic) and **data** needed…
- **Sampling** (autocorrelation)
- **Significant** variables for **regression** analysis?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



wildfire.com

Example 3: Criteria-Based Planning

- Suitablity 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:**

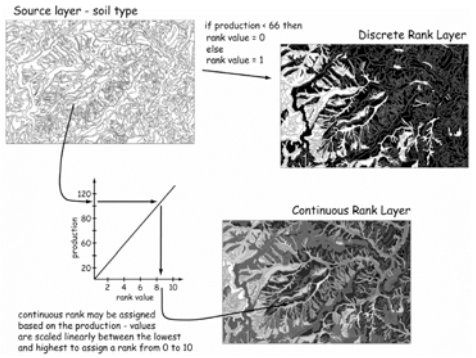
  temporally static, combined spatial datasets, operations and functions for problem-solving

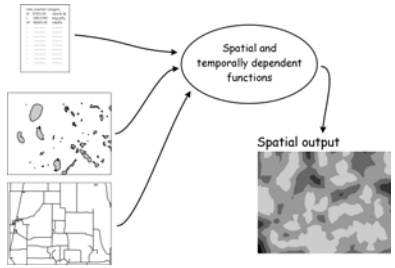
- **Spatio-temporal models**

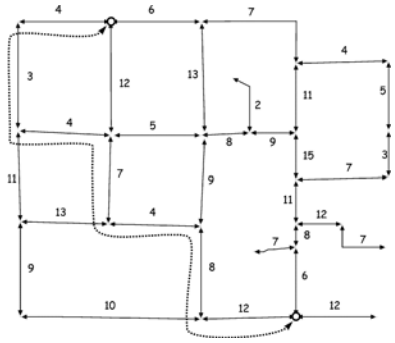
  dynamics in space and time, time-driven processes

- **Network models:**

  modeling of resources (flow, accumulation) as limited to networks

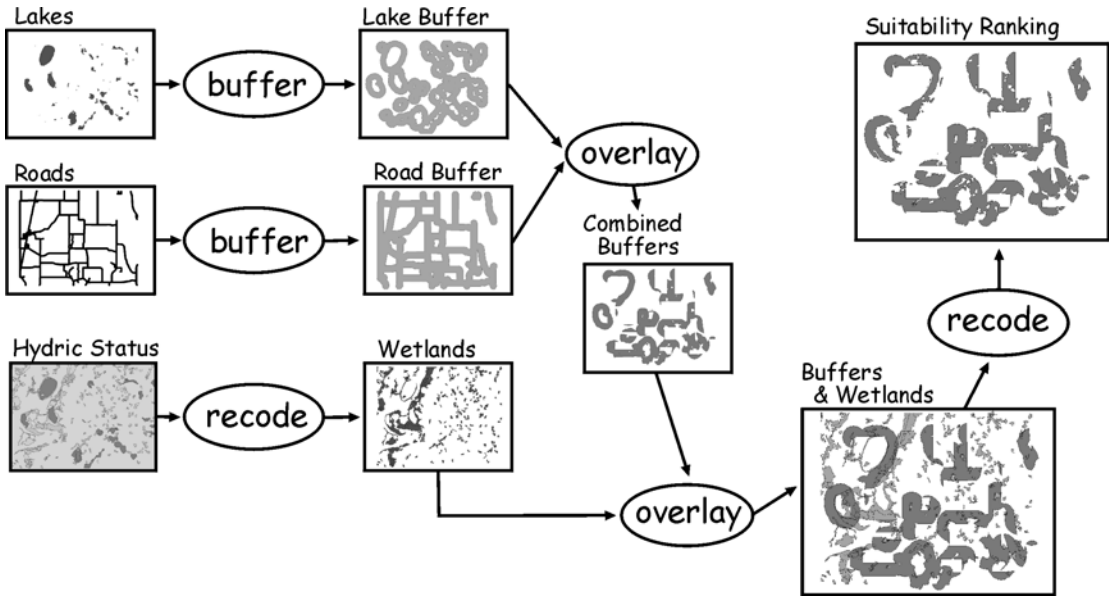


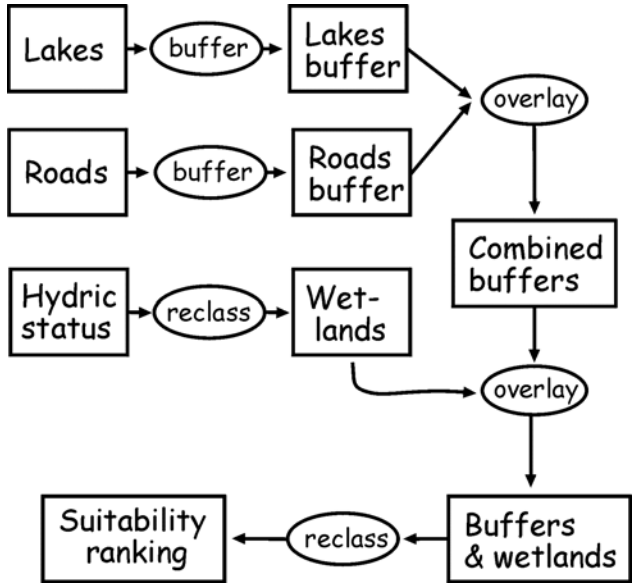




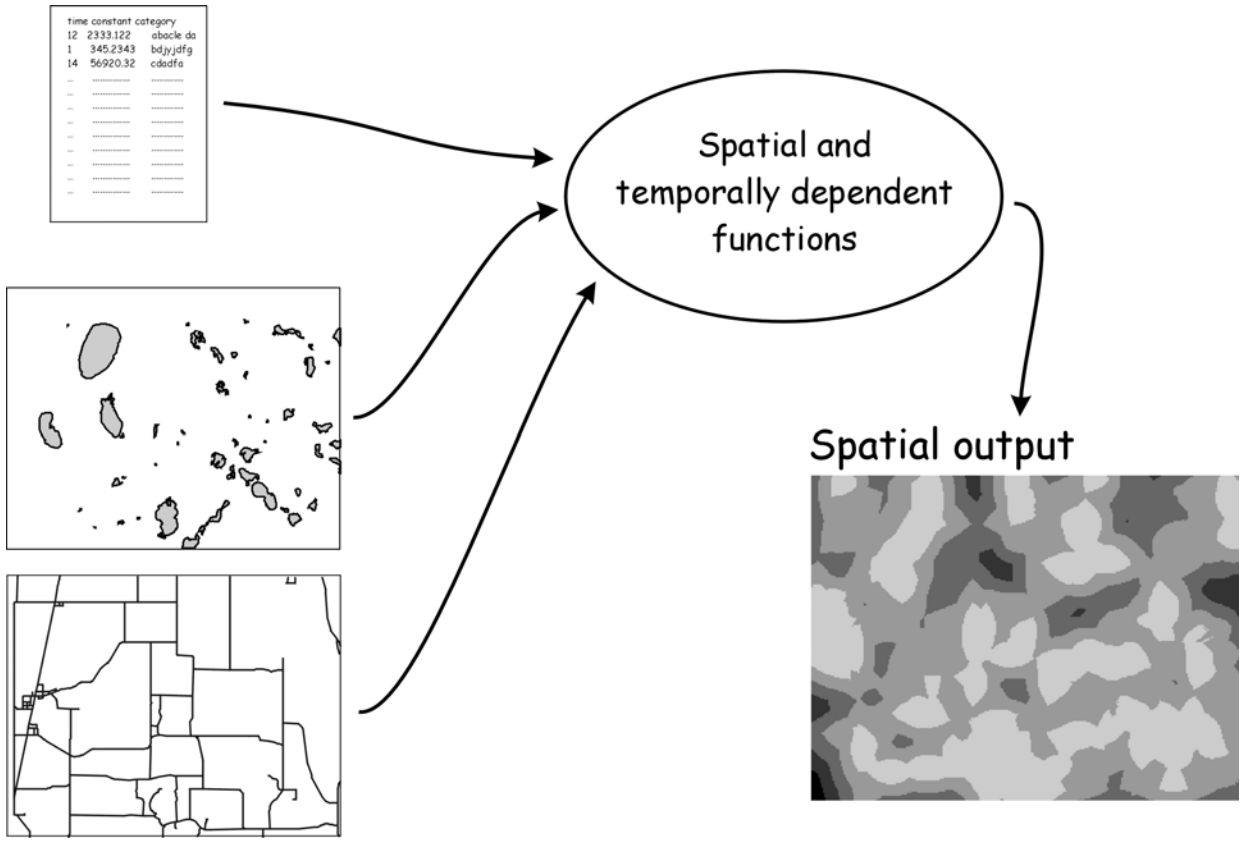
Cartographic Models

- Ranking and Weighting of criteria





Spatio-temporal Models



Spatial and 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

- Longley P.A., M. F. Goodchild, D. J. Maguire and D. W. Rhind. 2005. Geographic Information Systems and Science. Second Edition. John Wiley, Chichester, 2005.
- Goodchild, M.F. 2003. Geographic Information Science and Systems for Environmental Management. Annual Review of Environment and Resources. Vol. 28: 493-519.
- Burrough, P.A. and McDonnell, R.A. 1998. Principles of Geographical Information Systems. London: Oxford.
- Goodchild, M F. 1988. Modeling error in objects and fields. Accuracy of Spatial Databases Meeting; Montecito, CA; (USA); Dec. 1988. pp. 107-113. 1990
- Tomlin, C.D. 1991 Cartographic Modeling. In Maguire, D., Goodchild, M.F., and Rhind, D. (Eds.) Geographic Information Systems: Principles and Applications. London: Longman: 361 - 374.
- Goodchild, M. F., 1987, Towards an enumeration and classification of GIS functions. Proceedings, /CIS 87: the Research Agenda, edited by R. T. Aangeenbrug and Y. M. Schiffman (Washington, DC: NASA), **11,** 67-77.