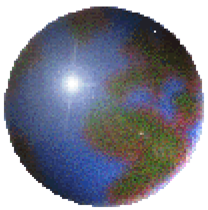


Chapter 2: Spatial Concepts and Data Models

Learning Objectives

- Learning Objectives (LO)
  - LO1: Understand concept of data models
    - What is a data model?
    - Why use data models?
  - LO2 : Understand the models of spatial information
  - LO3: Understand the 3-step design of databases
  - LO4: Learn about the trends in spatial data models
- Mapping Sections to learning objectives
  - LO2 - 2.1
  - LO3 - 2.2
  - LO4 - 2.3, 2.4

What is a Data Model?

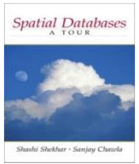
- What is a model? (Dictionary meaning)
  - A set of plans (blueprint drawing) for a building
  - A miniature representation of a system to analyze properties of interest

- What is Data Model?
  - Specify structure or schema of a data set
  - Document description of data
  - Facilitates early analysis of some properties, e.g. querying ability, redundancy, consistency, storage space requirements, etc.

- Examples:
  - GIS organize spatial set as a set of layers
  - Databases organize dataset as a collection of tables

Example

- **State-Park** SDB
  - consists of **Forests**
    - is a collection of **Forest-stands** (each has a tree species)
  - accessed by **roads**
  - has a **manager**
  - contains **fire-stations**
  - contains **facilities**
    - either **offices** or **camping groups**
  - includes **rivers**
    - provide water to facilities



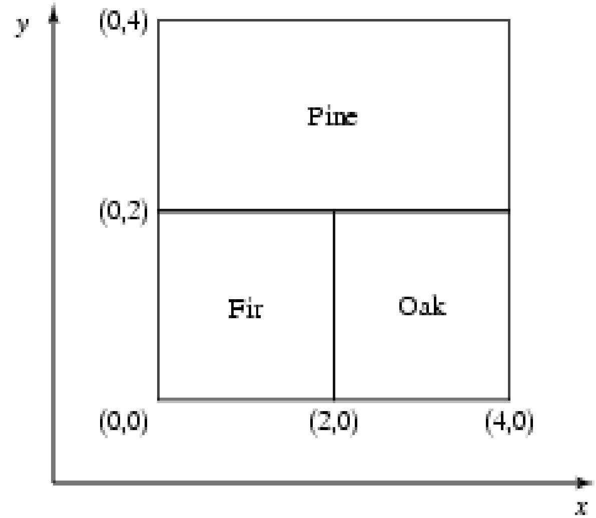
Learning Objectives

- Learning Objectives (LO)
  - LO1: Understand concept of data models
  - LO2 : Understand the models of spatial information
    - Field based model
    - Object based model
  - LO3: Understand the 3-step design of databases
  - LO4: Learn about the trends in spatial data models

- Mapping Sections to learning objectives
  - LO2 - 2.1
  - LO3 - 2.2
  - LO4 - 2.3, 2.4

2.1 Models of Spatial Information

- Two common models
  - Field based
  - Object based
- Example: Forest stands
  - Fig. 2.1
  - (a) forest stand map
  - (b) Object view has 3 polygons
  - (c) Field view has a function



(a)

Object Viewpoint of Forest Stands

Area-ID	Dominant Tree Species	Area/Boundary
FS1	Pine	[(0,2),(4,2),(4,4),(0,4)]
FS2	Fir	[(0,0),(2,0),(2,2),(0,2)]
FS3	Oak	[(2,0),(4,0),(4,2),(2,2)]

(b)

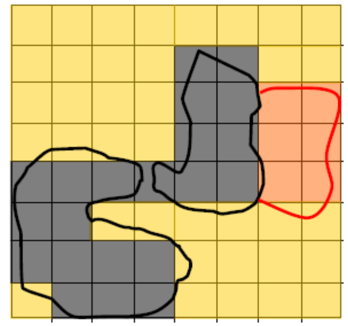
Field Viewpoint of Forest Stands

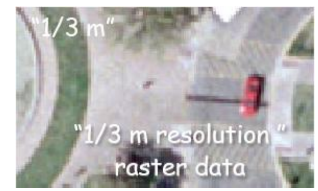
$$f(x,y) = \begin{cases} \text{"Pine,"} & 2 \leq x \leq 4 ; 2 < y \leq 4 \\ \text{"Fir,"} & 0 \leq x \leq 2; 0 \leq y \leq 2 \\ \text{"Oak,"} & 2 < x \leq 4; 0 \leq y \leq 2 \end{cases}$$

(c)

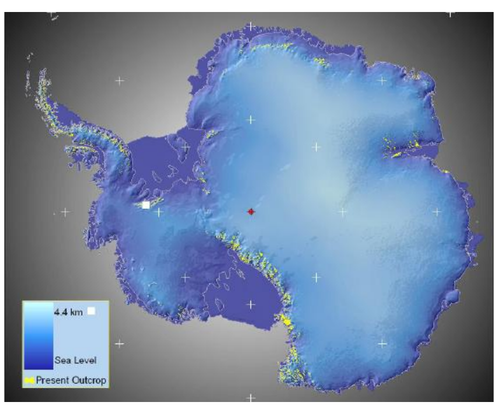
2.1.1 Field based (Raster) Model

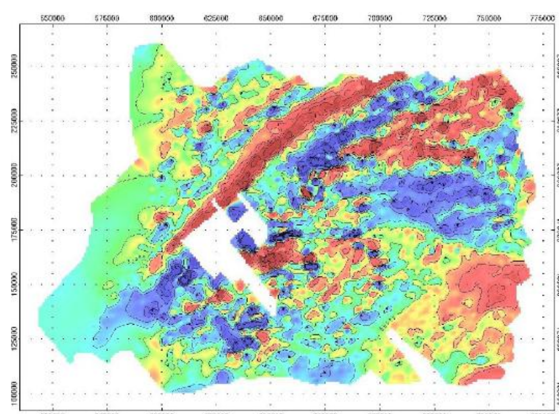
- Suitable for
  - amorphous phenomena
    - Fire, flood
  - continues quantities
    - temperature, depth, elevation
- Used mostly for
  - satellite images
  - sensor applications





Resolution vs. complexity (size and process)

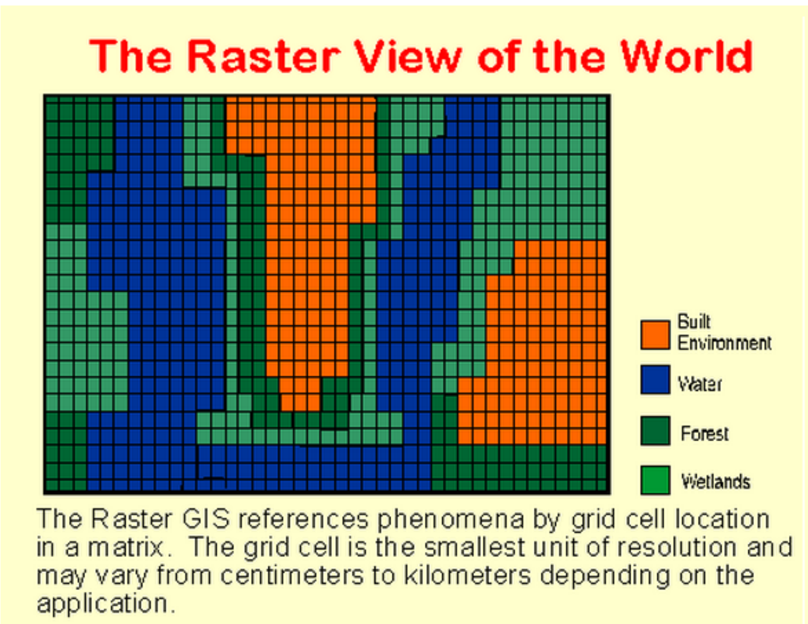


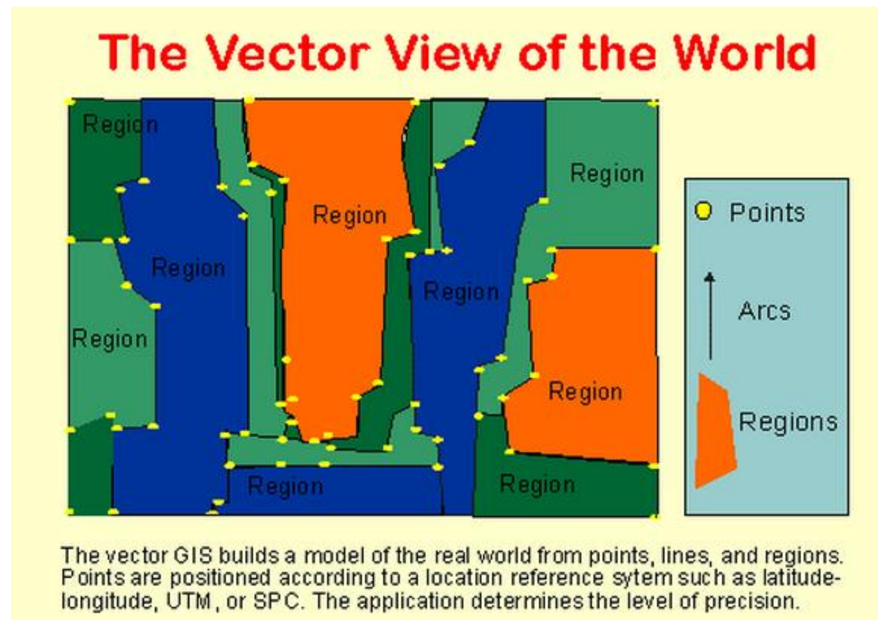


2.1.2 Object Model

- Object model concepts
  - Objects: distinct identifiable things relevant to an application
  - Objects have attributes and operations
  - Attribute: a simple (e.g. numeric, string) property of an object
  - Operations: function maps object attributes to other objects
- Example from a roadmap
  - Objects: roads, landmarks, ...
  - Attributes of road objects:
    - spatial: location, e.g. polygon boundary of land-parcel
    - non-spatial: name (e.g. Route 66), type (e.g. interstate, residential street), number of lanes, speed limit, ...
  - Operations on road objects: determine center line, determine length, determine intersection with other roads, ...

Raster vs Vector





Raster or Vector

Raster

- Simple data structure
- Ease of analytical operation
- Format for scanned or sensed data - easy, cheap data entry

But......

- Less compact
- Querry-based analysis difficult
- Coarser graphics
- More difficult to transform & project

Vector

- Compact data structure
- Efficient topology
- Sharper graphics
- Object-orientation better for some modeling

But....

- More complex data structure
- Overlay operations computationally intensive
- Not good for data with high degree of spatial variability
- Slow data entry

Conversions and errors

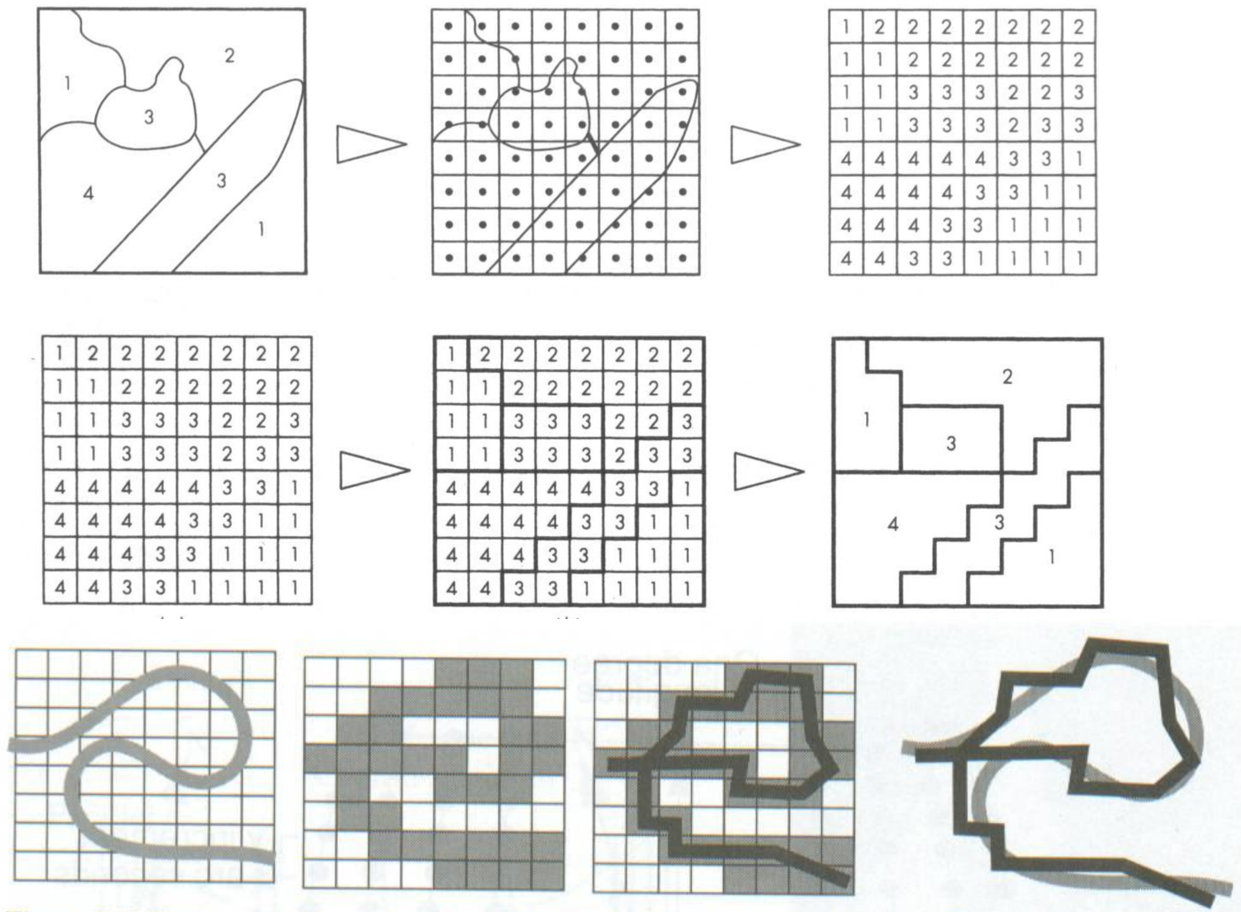


Figure 3.19 Errors caused by exchanging data between raster and vector formats. The original (gray) river after raster-to-vector conversion appears to connect the loop back.

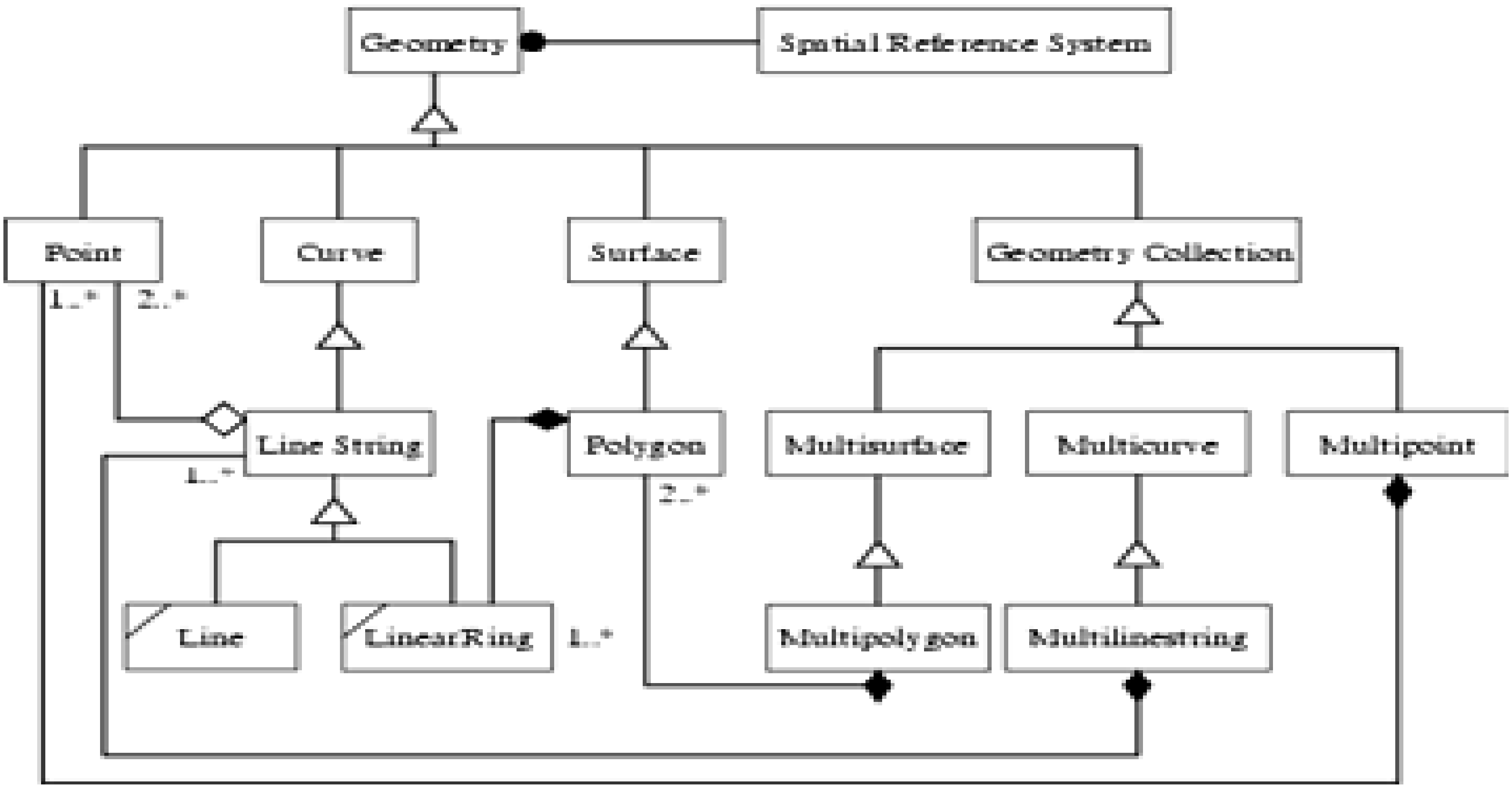
Classifying Spatial objects

- Spatial objets are spatial attributes of general objects
- Spatial objects are of many types
  - Simple
    - 0- dimensional (points), 1 dimensional (curves), 2 dimensional (surfaces)
    - Example given at the bottom of this slide
  - Collections
    - Polygon collection (e.g. boundary of Japan or Hawaii), …

Spatial Object Types	Example Object	Dimension
Point	City	0
Curve	River	1
Surface	Country	2

Spatial Object Types in OGIS Data Model

http://www.opengeospatial.org/standards



Classifying Operations on spatial objects in Object Model

- Classifying operations (Tables 2.1, 2.2, pp. 29-31)
  - Set based: 2-dimensional spatial objects (e.g. polygons) are sets of points
    - a set operation (e.g. intersection) of 2 polygons produce another polygon
  - Topological operations: Boundary of USA touches boundary of Canada
  - Directional: New York city is to east of Chicago
  - Metric: Chicago is about 700 miles from New York city.

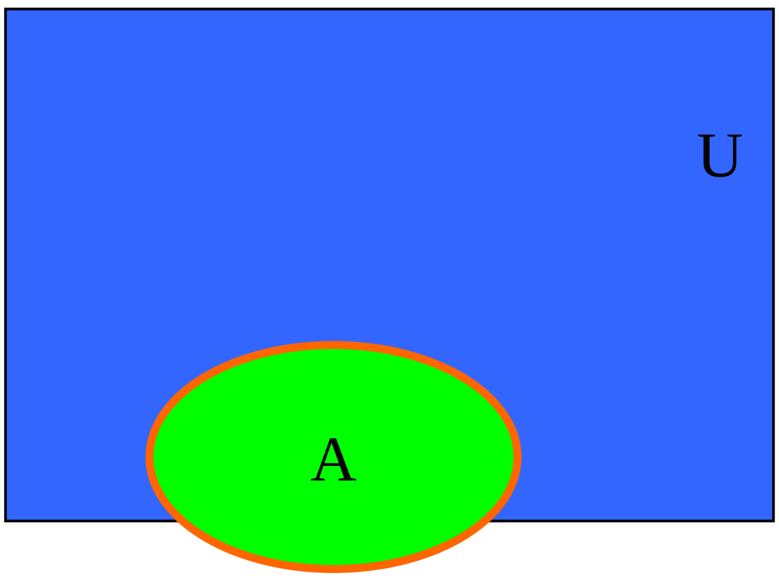
Set theory based	Union, Intersection, Containment,
Toplogical	Touches, Disjoint, Overlap, etc.
Directional	East,North-West, etc.
Metric	Distance

Topological Relationships

- Topological Relationships
  - invariant under elastic deformation (without tear, merge).
  - Two countries which touch each other in a planar paper map will continue to do so in spherical globe maps.
- Topology is the study of topological relationships
- Example queries with topological operations
  - What is the topological relationship between two objects A and B ?
  - Find all objects which have a given topological relationship to object A ?

Topological Concepts

- Interior, boundary, exterior
  - Let A be an object in a “Universe” U.



Green is A interior (A^o)

Red is boundary of A (∂A)

Blue –(Green + Red) is A exterior (A^-)

- Question: Define Interior, boundary, exterior on curves and points.

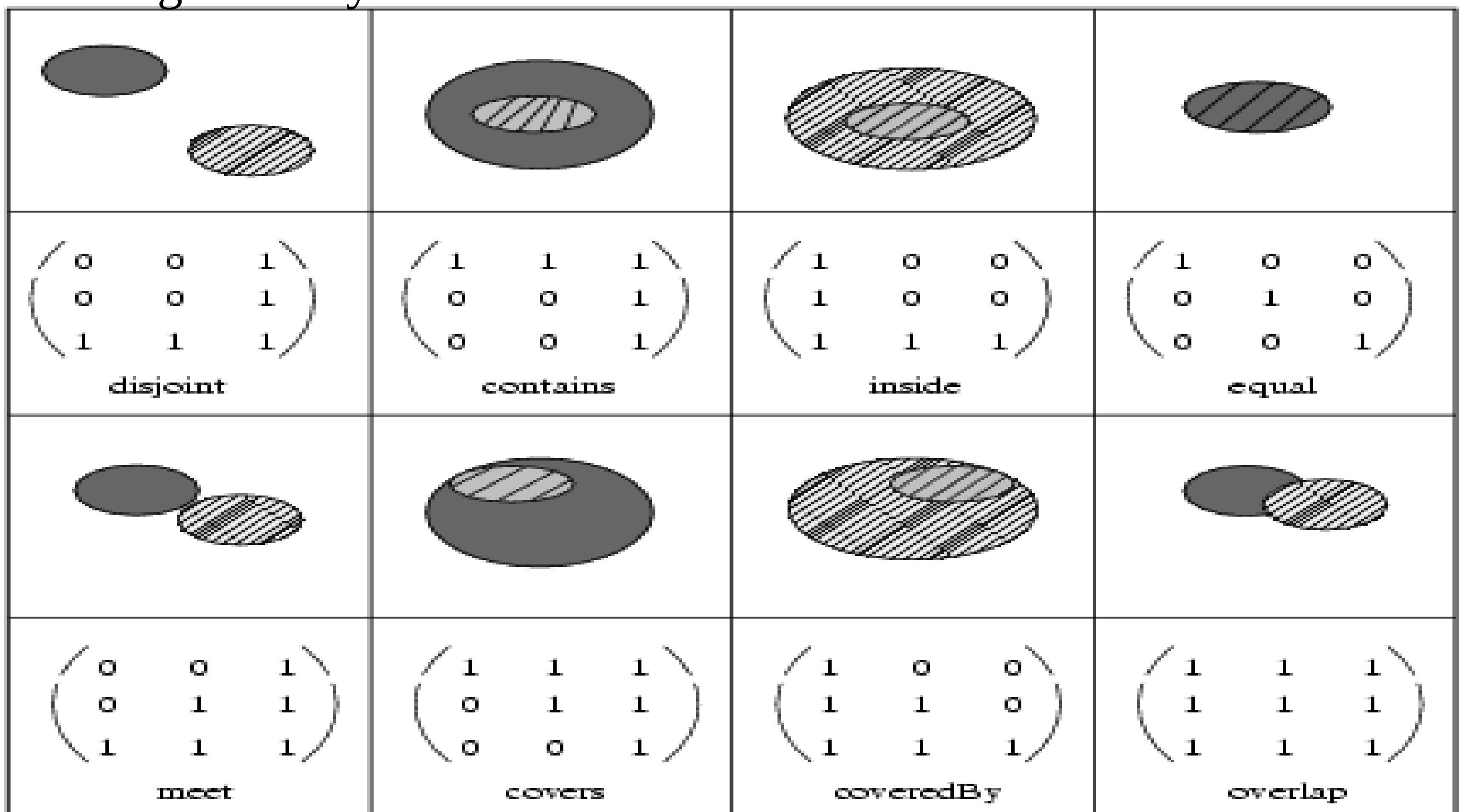
Nine-Intersection Model of Topological Relationships

- Many topological Relationship between A and B can be
  - specified using 9 intersection model
  - Examples on next slide
- Nine intersections
  - intersections between interior, boundary, exterior of A, B
  - A and B are spatial objects in a two dimensional plane.
  - Can be arranged as a 3 by 3 matrix
  - Matrix element take a value of 0 (false) or 1 (true).
- Q? Determine the number of many distinct 3 by 3 boolean matrices
- A: 2^9 = 512

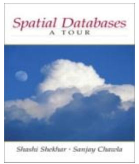
$$\Gamma_9(A,B) = \begin{pmatrix} A^\circ \cap B^\circ & A^\circ \cap \partial B & A^\circ \cap B^- \\ \partial A \cap B^\circ & \partial A \cap \partial B & \partial A \cap B^- \\ A^- \cap B^\circ & A^- \cap \partial B & A^- \cap B^- \end{pmatrix}$$

Specifying topological operation in 9-Intersection Model

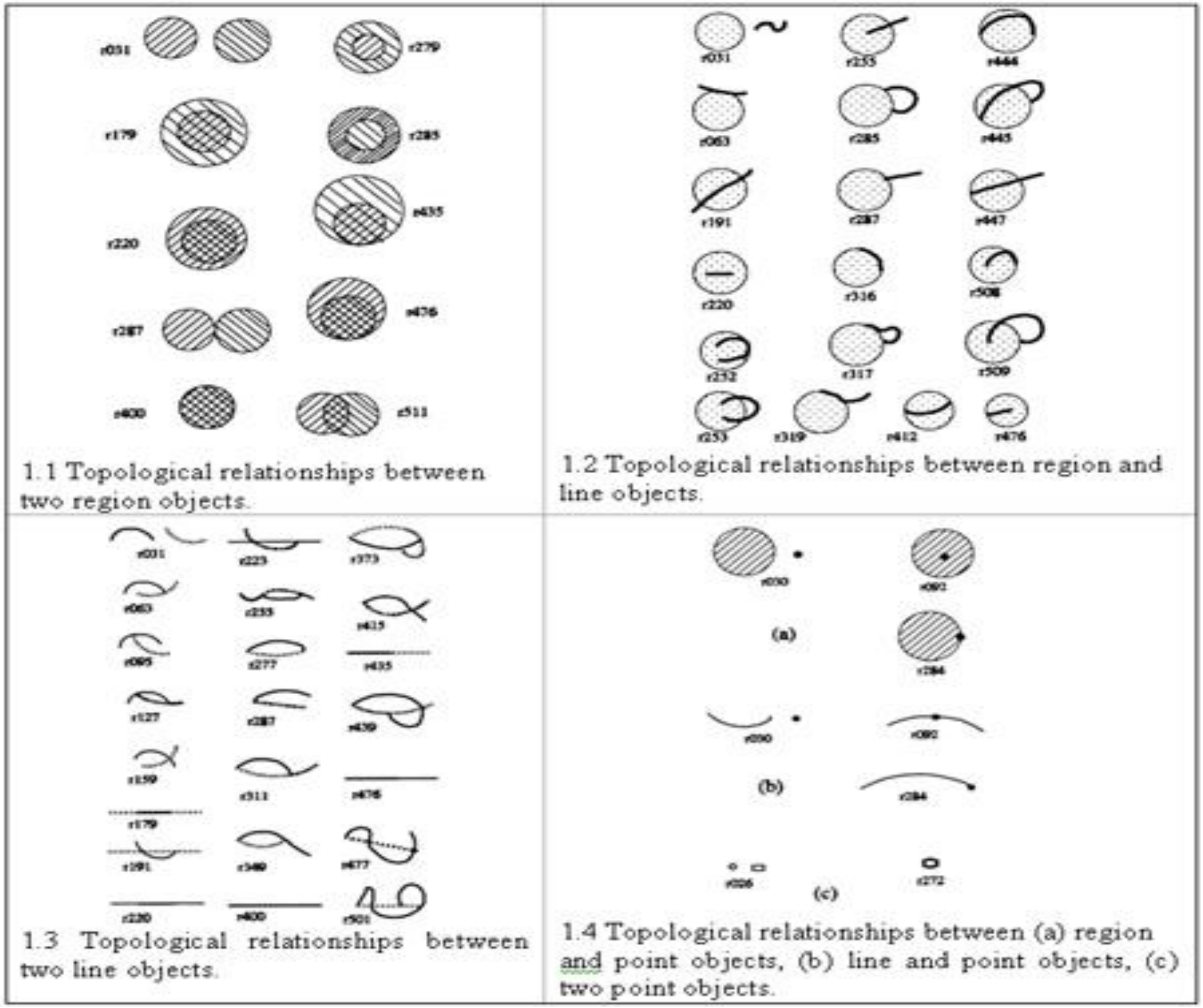
For 2-dim regions only 8 are realizable



Question: Can this model specify topological operation between a polygon and a curve?



Other cases



1.1 Topological relationships between two region objects.

1.2 Topological relationships between region and line objects.

1.3 Topological relationships between two line objects.

1.4 Topological relationships between (a) region and point objects, (b) line and point objects, (c) two point objects.

Using Object Model of Spatial Data

- Object model of spatial data
  - OGIS standard set of spatial data types and operations
  - Similar to the object model in computer software
  - Easily used with many computer software systems
  - Programming languages like Java, C++, Visual basic
    - Example use in a Java program
    - **Spatial Java Interface** (http://www.stanford.edu/dept/itss/docs/oracle/10g/appdev.101/b10826/sdo_intro.htm#BAJHICEH)
    - Spatial data library SDE ESRI

Example

- Write a simple Java program for the following query:
  - "Find all tourist offices within 10 miles from the Maple campground"
- Assume that Facilities have 3 attributes: name, type, location
- File format:
  - Name @@ Type @@ x-coord @@ y-coord
  - Maple @@ Campground @@ 2.0 @@ 3.0
- Define/use a class for 2-dim points

```
Each line in the file represents a facility; use @@ as its delimiter, e.g.
   Maple @@ campground @@ 2.0 @@ 3.0
   Office @@ Tourist-Office @@ 6.0 @@ 8.9

public class Facility {
   protected String name;
   protected String type;
   protected Point  location;

   public Facility (String name, String type, Point location) {
     this.name = name;
     this.type = type;
     this.location = location;
   }

   public String getName() {
     return name;
   }
   public boolean withinDistance(Facility f, double d) {
     if (this.location.distance(f.location) < d)
       return true;
     else
       return false;
   }
}
```

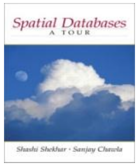
```
public class FacilitySet {
  const maxSize = 50;
  protected Facility[maxSize] facilityTable;

  /* read from file filename and initialize the facility table */
  public FacilitySet(String filename) {
    BufferedReader in = new BufferedReader (new FileReader(filename));
    String inline;
    StringTokenizer strLine;
    int i=0 ;
    String token;

    while ((inline = in.readLine())!= null) {
      strLine = new StringTokenizer(inline, "@@");

      /* read x coordinate */
      String type token = strLine.nextToken();
      FacilityTable[i++].location.y = Double.valueOf(token).doubleValue();

    }
  }
}
```




```
public class FacilityDemo {

  public static void main(String[] args) {

    Facility f = new Facility("Maple", "Campground", Point(2.0,4.0));
    Facility[] fTable = new FacilitySet("facilityFile");
    String[] resultTable = new string[fTable.length];

    int j=0;
    for (int i=0; i < fTable.length; i++) {
      if (f.withinDistance(fTable[i], 2.0)
        and fTable[i].type = "Tourist-Office")
         resultTable[j++] = fTable[i].name;
    }
  }
}
```

Summary questions

- A lake is usually modeled as an object (vector). Give an example that it my be useful to model it as a field (raster)
- Are the boundaries of the lake always well defined?
- Select the most natural data type (vector model) for the following entities:
  - countries, rivers, lakes, highways, cities
  - How do the selected types change with changes in scale?