Chapter 6

Spatial concepts and data models

-Niraj K.C.

Table of Content

- Models of spatial information: field based model, object-based models
- Spatial data types
- Operation on spatial objects: set oriented, topologies, directional, metric space, Euclidean
- ER model with spatial nation: extending ER model with pictogram
- Object oriented data modeling with UML, comparison between ER and UML

Database management system

- A place to organize, store and retrieve large amount of data easily.
- Used in all kinds of production and businesses.
- Silent success story of the information age.

Database management system

- Using SQL, DBMS allow us to ask queries like:
  - List the top 10 customers, in terms of sales, in year 2010.
  - List employee id and the corresponding salaries and sort them in decreasing order.
- However, traditional DBMS are either incapable or not user-friendly in answering spatial queries.

Spatial queries

- What are spatial queries?
  - What are the names of all the bookstores within 10 km of mahendrapool?
  - Which country have the most neighboring countries?
  - Where is the nearest gas station?
- Spatial data is generally more complex than traditional business data.
  - How to store different shapes?
  - How to conduct efficient queries on these data?

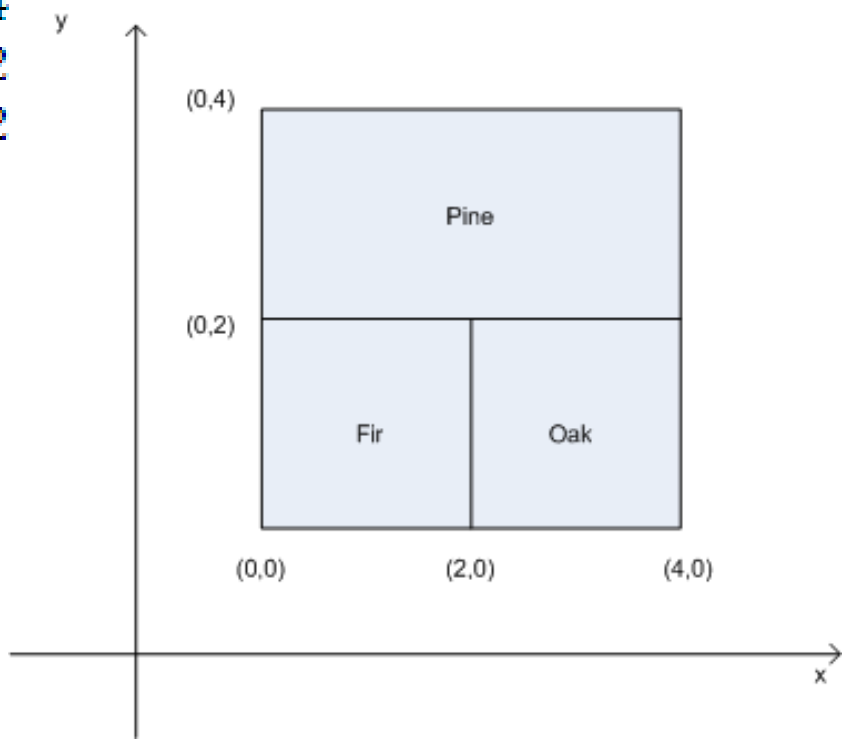
Spatial Data Model

- Field model
- Object model

State-park SDB example

- Field viewpoint

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



- Object viewpoint

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)]

Field model

- Three components:
  - Spatial framework
    - Euclidean space
    - Latitude longitude
  - Field function
    - F: spatial framework → Attribute domain(A_i)
    - {fir, oak, pine}
  - Field operation
    - Model relationship and interactions
    - Union, composition, etc.

Field model

- Field operation
  - Can be classified into three categories.
    - Local
      - Depends only on the value of the input field at that location
    - Focal
      - Depends on the values that the input field assumes in a small neighborhood of the location
    - Zonal
      - Associated with aggregate operation

Field operation

- Local
  - Depends only on the value of the input field at that location
  - Union is an example

$$f(x) = \begin{cases} 1, & if\ x = tree \\ 0, & otherwise \end{cases}$$

$$g(x) = \begin{cases} 1, & if\ x = lake \\ 0, & otherwise \end{cases}$$

$$(f+g)(x) = \begin{cases} 1, & if\ x = tree\ or\ lake \\ 0, & otherwise \end{cases}$$

Field operation

- Focal
  - Depends on the values that the input field assumes in a small neighborhood of the location
  - Analogy to differentiation
  - For example, if f(x,y) is defined as the elevation of point (x,y), then inclination(gradient) at (x,y) is a kind of focal operation

$$\frac{df}{dxdy}$$

Field operation

- Zonal
  - Associated with aggregate operation
  - Analogy to integration
  - For example, if f(x,y) is defined as the elevation of point (x,y), then average elevation of an area is a kind of zonal operation

$$\iint_{x\ y} f(x,y)\,dx\,dy \Big/ Area(x,y)$$

Object model

- Abstract spatial information into distinct, identifiable and relevant things, or entities, which are called objects.
- Data are modeled as attributes of interests
  - Non-spatial(“Fir” is alphanumeric attribute)
  - Spatial (Polygon represents its spatial extend is spatial attribute)

Object model

- OGIS' proposed building blocks of spatial geometry in UML notation.

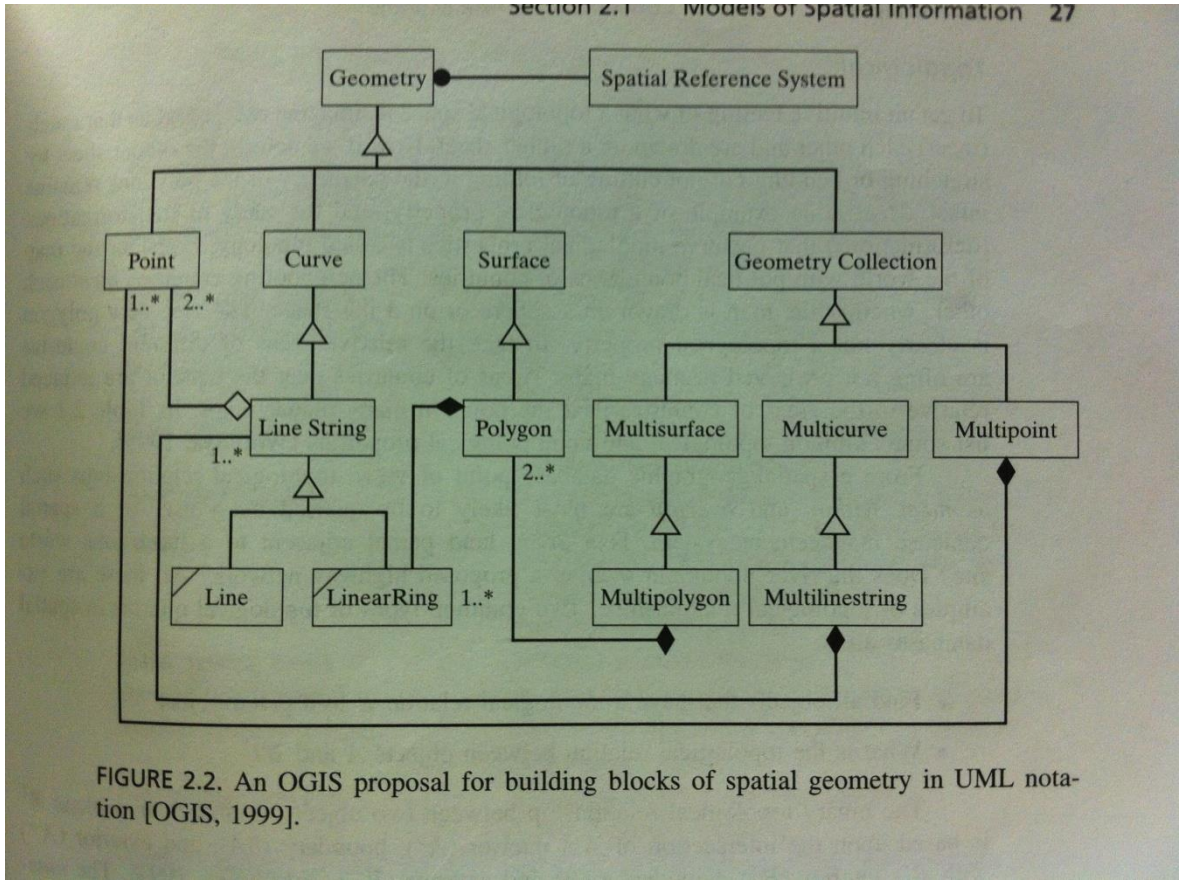


FIGURE 2.2. An OGIS proposal for building blocks of spatial geometry in UML notation [OGIS, 1999].

Operations on spatial objects

- Set-oriented
- Topological
- Directional
- Metric space
- Euclidean

Set-oriented operation

- Simplest and most general
- Adequately modeled by set theory
- Union, intersection, containment, membership, etc.
  - Hierarchical relationships
    - Forest-stand contained in forest
  - Is Shanghai a city of China?

Topological

- Topology is mathematics concerned with spatial properties that are preserved under continuous deformation of objects.
- Think topological properties as those which can be draw on a rubber sheet and preserved when the rubber is stretched or bended.

Topological

- Neighboring countries meet each other no matter on a flat map or a sphere.
- Meet, within, overlap, open, closed are topological properties
- Area, distance, length are non-topological properties
  - Which country have the most neighboring countries?

Directional

- Absolute
  - North, South, East, West, etc.
- Object-relative
  - Front, Behind, Above, Left, etc.
- Viewer based
  - Left, Right, etc.

Metric space

- Metric space is a set X for any pair of points x and y in X, a real number d(x,y), called the distance from x to y, is defined and have the following properties:
  - D(x,y) >= 0 and d(x,x) = 0
  - D(x,y) = d(y,x)
  - D(x,y) <= d(x,z) + d(z,y)
- Within a metric space, topological properties can be defined.
  - What are the names of all the bookstores within 10 km of mahendrapool?
  - Where is the nearest gas station?

Euclidean

- Euclidean is a vector space over real numbers.
- Vector space is a set V with the following two operations defined:
  - Addition: u+v in V for all u, v in V
  - Product: au in V for real a, v in V
- All previously mentioned relationships, including set-oriented, topological, metric, directional can be defined on vector space.

Comparison of the two models

- Which one to choose?
  - Based on the requirement of the application.
  - Field model is better at modeling “continuous” or “dynamic” data
    - Elevation
    - Temperature
  - Object model is better at modeling transportation networks, land parcels for property tax, etc.

Conclusion

- The above two models only give a way to abstract spatial data and relationship.
- It does not provide any information on how to store, query in these model.
- Modeling spatial data is challenging and the specific task at hand determines the best way to model the data.

Assignment 6

1. What do you understand by spatial model? Mention its types and explain them in brief with their spatial operations.
2. Briefly explain the three steps of database design with suitable example.
3. How ER model are mapped into the relational model?
4. How ER model are extends with spatial concepts (Pictograms)?
5. Describe Object oriented data modelling with UML in detail .
6. Compare and contrast
   a) ER Model and UML Model
   b) Focal operation and Zonal operation
   c) Euclidean space and Metric space
   d) Topological and set oriented operation
   e) Topological and directional operation