

Spatial Objects and their Representation

Models

Model: Abstraction of reality following formal rules

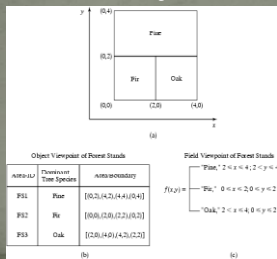
- e.g. Euclidean space for physical space

At different levels:

- mathematical model (Euclidean space)
- conceptual design model (ER model)
- data model (design)
- data formats (implementation)

Data Models

- object model (entity, feature-based)
- field based model (space-based)



from Shekhar/Chawla

Field Model

based on Shekhar/Chawla

Example

WGS-84 Geoid Heights (-180 to 170), ten by ten
 90 Degrees N: 13,13
 80 Degrees N: 3,1,-2,-3,-3,-3,-1,1,5,9,11,19,27,31,34,33,34,-33,34,-28,23,17,13,9,4,1,-2,-2,0,2,3,2,1,1
 ...

WGS-84 Geoid Height

From DMA 10 by 10 Degree Geoid Height Grid

from http://www.colorado.edu/geography/gcraft/notes/datum/datum_f.html

Field Model Concepts

- Spatial Framework
 - partitioning of space
 - e.g., grid (Latitude and Longitude)
- Field Functions:
 - f: Spatial Framework → Attribute Domain
- Field Operations
 - Examples, addition(+) and composition(o).

$$f + g : x \rightarrow f(x) + g(x)$$

$$f \circ g : x \rightarrow f(g(x))$$

Types of Field Operations

- **Local:** value at a given depends only on the value of the field at that location (e.g., Thresholding)
- **Focal:** value depends on the values in a small neighborhood of the location (e.g., slope)
- **Zonal:** aggregating (integrating) values over a zone (e.g. calculating the average height of the trees for each species)
- **Exercise:** Classify following operations on elevation field
 - (I) Identify peaks (points higher than its neighbors)
 - (II) Identify mountain ranges (elevation over 2000 feet)
 - (III) Determine average elevation of a set of river basins

Object Model

Object Model: Geometry

One-dimensional objects (with possible properties)

- point
- polyline (simple, monotone)
- polygon (simple, monotone, convex)

Two-dimensional

- region (boundary, monotone, connected)

Modes of Spatial Representation

Spatial Modes

how to discretize problem?

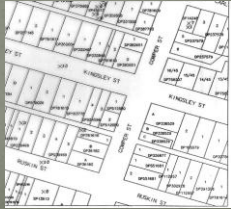
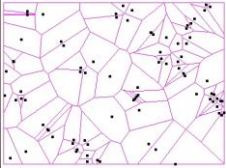
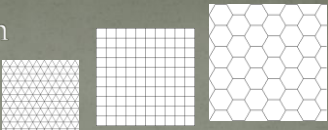
- Tessellation
- Vector
- Half-Plane

Tessellation

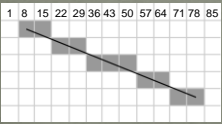
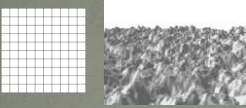


Tessellation

- grid
- cadastral
- Thiessen cells/pixels



Data in Tessellation mode

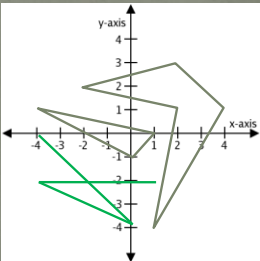


1 8 15 22 29 36 43 50 57 64 71 78 85

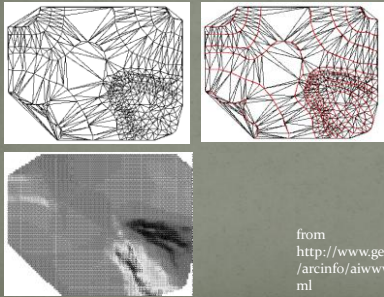
9, 16, 24, 31, 39, 46, 53, 61, 68, 76, 83

Vector-mode – object based

point: [x: real, y: real]
polyline: <point>
polygon: <point>
region: {polygon}

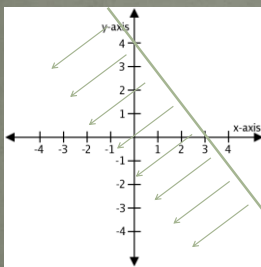


Vector-mode – field based



from
<http://www.geog.buffalo.edu/arcinfo/aivwtut/step3.html>

Half-planes



$$y = -4/3 x + 4$$

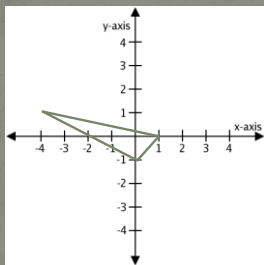
$$4x + 3y \leq 12$$

$$(4,3) (x,y) \leq 12$$

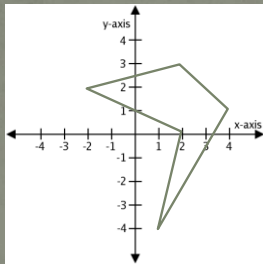
$$(1/3, 1/4) (x,y) \leq 1$$

In general: $ax \leq 1$

Half-planes for polygons



Half-planes for all polygons ?



Collections of Objects

- Spaghetti
 - collection of objects, no topological data stored
- Network
 - captures connectivity between points
- Topological
 - captures connectivity between points and adjacency between regions

Network model

point: [x: real, y: real]
 node: [point, <arc>]
 arc: [start-node, end-node, <point>]
 polygon: < point>
 region: {polygon}

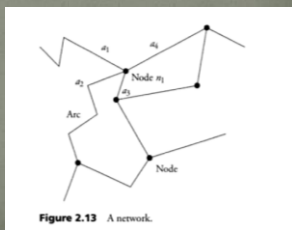
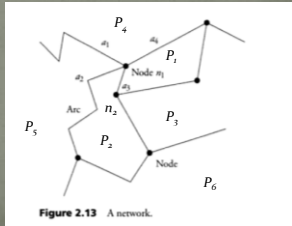


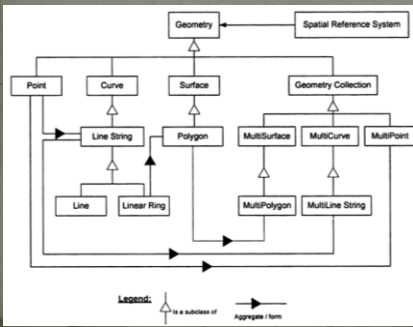
Figure 2.13 A network.

Topological model

point: [x: real, y: real]
 node: [point, <arc>]
 arc: [start-node, end-node, left-polygon, right-polygon, <point>]
 polygon: < point>
 region: {polygon}



OGC Geometry Object Model



from Yeung-Hall, "Spatial database systems"

Data Formats

Popular spatial data formats

Raster (field-based)

- jpeg
- ESRI-Grid
- TIFF (tagged image file format)

Vector (object-based)

- DXF
- GML (and KML), WKT
- shapefile
- TIGER/Line

WKT (Well-Known Text)

- specify geometry
 - POINT(o o)
 - LINESTRING(o o, 1 o, 1 1)
 - POLYGON((o o, 1 o, 1 1, 0 1, 0 0),(- 2 -2, -2 2, 2 2, 2 -2, - 2 -2))
 - MULTIPOINT(o o, 1 o 5.5, 5 3.7)
 - MULTILINESTRING
 - MULTIPOLYGON
 - GEOMETRYCOLLECTION(POINT(2 3), POLYGON(2 3, 2 4, 3 4, 2 3))
- specify spatial reference system

WKT (Spatial Reference System)

```

COMP_CS["OSGB36 / British National Grid + 000",
PROJCS["OSGB 1936 / British National Grid",
GEOGCS["OSGB 1936",
DATUM["OSGB 1936",
SPHEROID["Airy 1830", 6377563.396, 199.3249646, AUTHORITY["EPSG", "7001"]],
TOWERS["175, -111, 431, 0, 0, 0, 0"],
AUTHORITY["EPSG", "42771"]],
PRIMEM["Greenwich", 0, AUTHORITY["EPSG", "8901"]],
UNIT["Meter", 0.017483312199993, AUTHORITY["EPSG", "9108"]],
AXIS["X", EAST],
AXIS["Y", NORTH],
AUTHORITY["EPSG", "42771"]],
PROJECTION["Transverse_Mercator"],
PARAMETER["latitude_of_origin", 49],
PARAMETER["central_meridian", -1],
PARAMETER["false_easting", 0.999601721],
PARAMETER["false_northing", 0.999601721],
PARAMETER["scale_mertling", -100000],
UNIT["Meter", 1, AUTHORITY["EPSG", "9001"]],
AXIS["X", EAST],
AXIS["Y", NORTH],
AUTHORITY["EPSG", "27700"]],
VECT_CS["OSGB36"]],
VECT_DATUM["OSGB 1936", 1000, AUTHORITY["EPSG", "5101"]],
UNIT["Meter", 1, AUTHORITY["EPSG", "9001"]],
AXIS["X", EAST],
AUTHORITY["EPSG", "42771"]],
AUTHORITY["EPSG", "27700"]]]]

```

TIGER/Line[®]

- Topologically Integrated Geographic Encoding and Referencing system
- Created by the U.S. Census Bureau
- contains geographic data such as
 - streets, names
 - rivers
 - railroads
 - states, counties, districts (US, Puerto Rico)
 - zip codes, address ranges
 - important locations (schools, airports)
- Replaced by TIGER/Line shapefiles in 2007/8



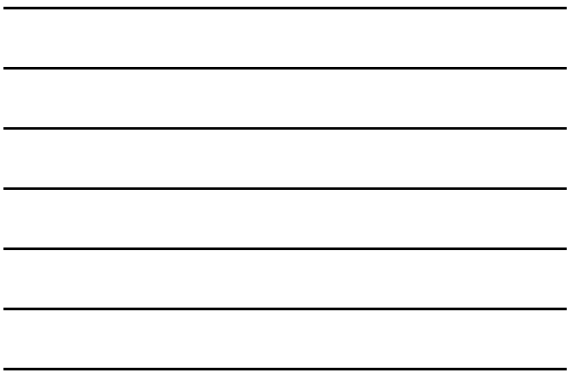
TIGER/Line

Shape points that describe the complete chain

- points:
 - node
 - shape (geometry)
 - entity (landmark)
- lines:
 - complete chain
 - network chain
- polygons:
 - GT-polygon

Legend:

- ⊙ Node
- ⊞ Shape point
- ⊙-⊙ Complete chain
- ⊞-⊞ Entry point
- ⊞-⊙ Polygon interior points
- ⊙-⊞ Network chain



Files

Table 2.1 Examples of record type 1 (chains).

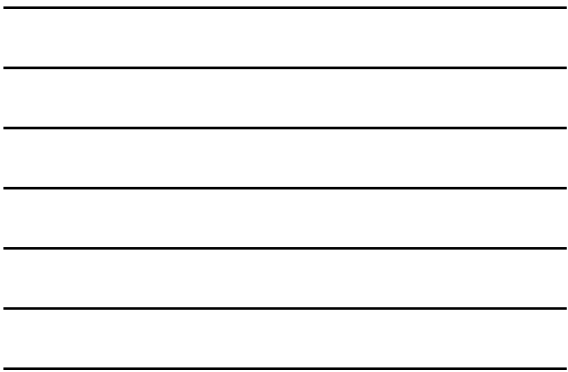
TLID	FRLONG	FRLAT	TOLONG	TOLAT
...
8086	-72156546	+41957498	-72161936	+41958117
8087	-72197129	+41957206	-72197197	+41957669
...

Table 2.2 Examples of record type 2 (shape points).

TLID	RTSQ	LONG1	LAT1	...	LONG10	LAT10
...
8086	1	-72156638	+41957658	...	-72157985	+41958184
8086	2	-72161599	+41958117	0	0	0
...

Table 2.3 Examples of record type 1 (link chains/polygons).

TLID	CENIDL	POLYIDL	CENIDR	POLYIDR
...
8086	PO123	1	PO1987	1
...



TIGER/Line Shapefiles

- TIGER/Line: ASCII Files, "home-grown database"
- Shapefiles: Oracle databases, shapefile format
 - .shp - the feature geometry
 - .shx - index of the feature geometry
 - .dbf - attribute information
 - .prj - coordinate system information (in well-known text)
 - .shp.xml - metadata in xml

KML

- Keyhole Markup Language (XML)
- OGIS standard developed by Google (for Google Earth)
- describe geographic locations

```

<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://www.opengis.net/kml/2.2">
  <Placemark>
    <name>CDM</name>
    <description>DePaul CDM building</description>
    <Point>
      <coordinates> -87.62583, 41.87845, 0</coordinates>
    </Point>
  </Placemark>
</kml>

```
