Topology

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Object Relationships

- **Relationships between GIS objects**
  - Spatial relationships
  - Relationships as attributes

Feature relationships

- There are vast number of possible relationships in spatial data.
- Relationships are important in GIS analysis.
  - *"is contained in"*
  - *"intersects"*
- Relationships can exist between entities of the same type or of different types.

Types of relationship

- **Relationships which are used to construct complex objects from simple primitives.**
  - ***Relationship between a line and the ordered set of points which defines it.***
  - ***Relationship between a polygon and the ordered set of lines which defines it.***
- **Relationships which can be computed from the coordinates of the objects .**
  - ***Areas can be examined to see which one encloses a given point - the "is contained in" relationship can be computed.***
  - ***Areas can be examined to see if they overlap - the "overlaps" relationship.***
- **Relationships which cannot be computed from coordinates**
  - ***We can compute if two lines cross, but not if the highways they represent intersect (may be an overpass).***

Entity Relations

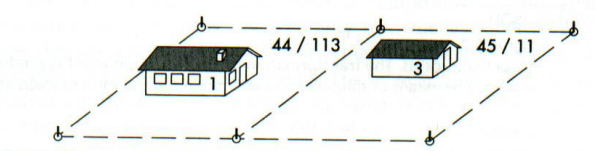
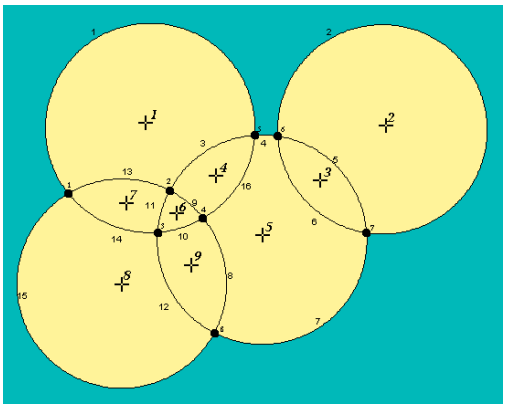


Figure 3.5
The computer cannot see the real world so it is necessary to specify the various relations between entities, such as *belong to, comprise, are located in/on,* and *border on.*

Spatial relationships



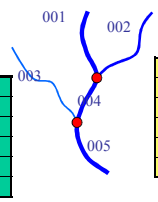
Spatial relationships

- **Point-point**
  - "is within"
  - "is nearest to",
- **Point-line**
  - "ends at",
  - "is nearest to"
- **Point-Polygon**
  - "is contained in",
  - "can be seen from",
- **Line-line**
  - "crosses",
  - "comes within",
  - "flows into",
- **Line-polygon**
  - "crosses",
  - "borders",
- **Polygon-Polygon.**
  - "overlaps",
  - "is nearest to",
  - "is adjacent to",

Relationships as attributes

- Example: "Flows-in" relationship

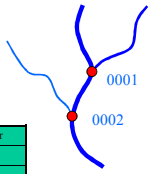
Option A



Link ID	Downstream
001	004
002	004
003	005
004	005
005	empty

Each stream link in a stream network could be given the ID of the downstream link which it flows into
Flow could be traced from link to link by following pointers

Option B



Link ID	Pointer
001	0001
002	0001
003	0002
004	0002
005	empty

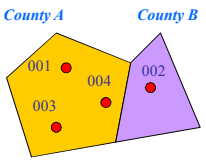
Point ID	Pointer
0001	004
0002	005

Each stream link in a stream network could be given the ID of the downstream point which it flows into
Each stream point in a stream network could be given the ID of the downstream link which it flows into
Flow could be traced from link to link by following pointers

Relationships as attributes

- Example: "is contained in" relationship

1. Find the containing county of each well (compute the "is contained in" relationship).
2. Store the result as a new attribute, County, of each well.
3. Using this revised attribute table, total flow by county and add results to the county table.



Well ID	County
001	A
002	B
003	A
004	A

County ID	No. of Wells
A	3
B	1

Topology

- "A GIS topology is a ***set of rules*** and ***behaviors*** that ***model how points, lines, and polygons share Geometry***" ***ESRI***

- "Topology is the science and mathematics of ***relationships*** used to ***validate the geometry*** of ***vector*** entities, and for operations such as ***network*** tracing and tests of polygon ***adjacency***" ***Longley***

Topology is a mathematics approach that defines unchangeable spatial relationships.

Spatial relationships and Topology

- When a map is stretched or distorted, some properties change**,**
  - Distance
  - Angles
  - Relative proximities
- Some properties won't change,
  - Adjacencies
  - Most other relationships, such as "is contained in", "crosses"
  - Types of spatial objects - areas remain areas, lines remain lines, points remain points
- These unchanged properties are called topological properties.

Advantages of Topology

1. Efficient data storage, Quick Processing of large data set
2. Spatial model operations

Types of Topological Relationships

1) Connectivity
• Indicates which geographic features connect to others or which geographic features intersect each other;

2) Adjacency
• Indicates which geographic features are adjacent (contiguous) to others;

3) Containment (Nestedness, Insideness)
• Indicates which geographic features (node, arc, smaller polygon) are contained within a polygon.

4) Proximity
• Indicates which geographic features are near others;

5) Relative Direction
• Indicates the relative position between geographic features;

Representation of Connectivity by Arc-node Topology

• An arc is defined by two endpoints, the from-node indicating where the arc begins and a to-node indicating where it ends. This **arc-node topology** indicates which arcs are connected at which nodes;

• Arc-node topology is supported through an arc-node list. Connected arcs are determined by searching through the list for **common node numbers**.

• A set of connected arcs can define a network.

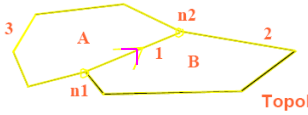
Representation of Direction by from-node and to-node

- The from-node and to-node define an arc and also indicates an arc's direction;
- This makes it possible to represent flow data;

Representation of Adjacency

- Two geographic features that share a boundary are called adjacent.
- For each arc, the polygons on its left and right can be determined from the arc's direction. This is referred to as left-right topology.

Topology



Topological Arcs File

Arc	*From*	*To*	*PL*	*PR*	*n1x*	*n1y*	*n2x*	*n2y*
1	n1	n2	A	B	x	y	x	y

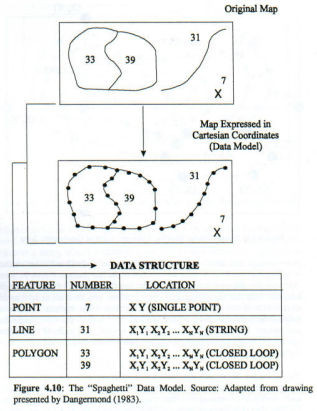
Figure 3.5 A topological structure for the arcs.

Spaghetti Vector Structure

Different points, lines and polygons are stored as independent objects
A line is recorded as a series of ordered points with x, y coordinate pairs
- Each polygon is encoded as a closed loop of points with coordinates that define the boundary of each closed area
- Each polygon is then stored as an independent feature.
- Lines between adjacent polygons are digitized and stored twice
- By maintaining each polygon as separate entity no explicit topological information is coded to show the connectivity and neighboring relationship.
- Simple structure and relatively efficient for cartographic display. Adopted by most CAD database

Spaghetti

- simple
- easy to manage
- no topology
- lots of duplication, hence need for large storage space
- very often used in CAC (computer assisted cartography

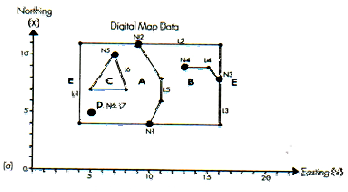


FEATURE	NUMBER	LOCATION
POINT	7	X Y (SINGLE POINT)
LINE	31	$X_1Y_1, X_2Y_2 \ldots X_nY_n$ (STRING)
POLYGON	33	$X_1Y_1, X_2Y_2 \ldots X_nY_n$ (CLOSED LOOP)
	39	$X_1Y_1, X_2Y_2 \ldots X_nY_n$ (CLOSED LOOP)

Figure 4.10: The "Spaghetti" Data Model. Source: Adapted from drawing presented by Dangermond (1983).

Source: Lakhan, V. Chris. (1996). *Introductory Geographical Information Systems*. p. 54.

Topological Model



(a)

(b)

POLYGON TOPOLOGY

Polygon	Links
A	L1, L5
B	L2, L3, L5
C	L6
D	L7
E	L1, L2, L3

(c)

NODE TOPOLOGY

Node	Links
N1	L1, L3, L5
N2	L1, L2, L5
N3	L2, L3, L4
N4	L4
N5	L6
N6	L7

(d)

LINK TOPOLOGY

Links	Start node	End node	Left polygon	Right polygon
L1	N3	N2	E	A
L2	N2	N3	E	B
L3	N3	N1	E	B
L4	N3	N4	B	B
L5	N2	N1	B	A
L6	N5	N5	A	C
L7	N6	N6	A	A

(e)

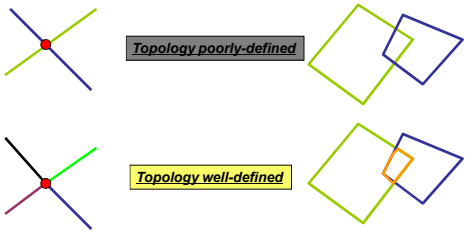
LINK COORDINATES

link	Coordinates			
L1	4,10	4,4	11,4	11,9
L2	11,9	11,16	8,16	
L3	8,16	4,16	4,10	
L4	8,16	9,13	9,13	
L5	11,9	8,11	6,11	4,10
L6	10,7	7,8	7,5	10,7
L7	5,5			

Bernhardsen, Tor. (1999). 2nd Ed. *Geographic Information Systems: An Introduction*. p. 62. fig. 4.12.

Topological examples

Network connectivity ***Polygon adjacency***



Topology poorly-defined

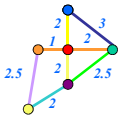
Topology well-defined

Importance of topology

- Topology enables operations like connectivity and contiguity analysis.
  - Searching a shortest path
  - Finding a service area by using a road network
  - Finding adjacent areas

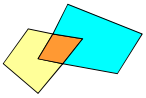
Topology and GIS analysis

Searching a shortest path



The shortest path from the blue point to the yellow point is through the red point and then the orange point (2+1+2.5=5.5 map units). However, if the topology of the red point is not defined clearly, which means the two yellow lines are consider as one and the two orange lines are considered as one, the resulting answer will be wrong (2+2+2=6 map units).

The overlapped two polygons have to be cut into three in order to clearly defined the spatial topology. Otherwise \ there will be difficulties finding an adjacent polygon of either.



Finding adjacent areas