GEOG 204

LECTURE 4
Spatial Analysis

1

Spatial Analysis

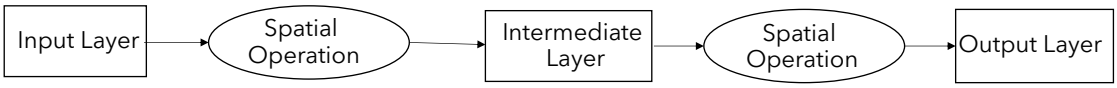
- In a GIS,
  - Data are usually grouped into layers (or themes).
  - The analysis functions of a GIS use both spatial and non-spatial data
  - Analysis functions are used
    - for maintenance of the data
    - Computing new information from the data
- Spatial Analysis can be viewed as:
  - Operations that use spatial data to derive new spatial information.
  - The most distinguishing purpose of a GIS

2

2

Spatial Analysis

- Involves using data from one or more layers to create a new output.
- Could be:
  - single operation applied to a data layer
  - many operations that integrate input data from many layers or sources to create the desired output.



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3

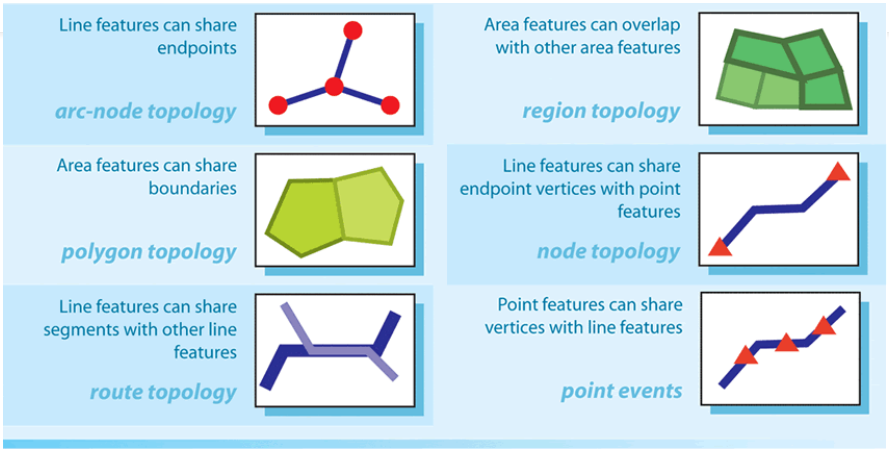
Topology

- Topology: The spatial relationships between adjacent or neighboring features.
  - Based on 3 basic elements: Adjacency, Containment and Connectivity
  - Allows analyses like as contiguity, containment, connectivity, overlap…
    - For example, it is used in routing through linear networks. Routes cannot be established through the network if the line features do not share nodes/vertices.

4

4

Topology



Source: ESRI

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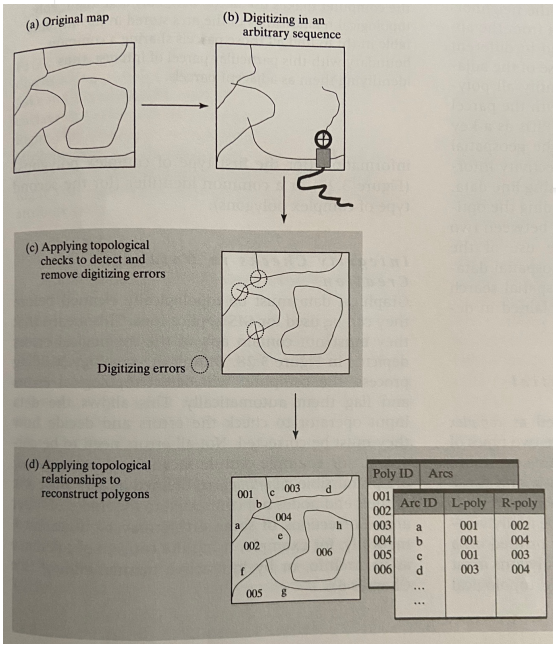


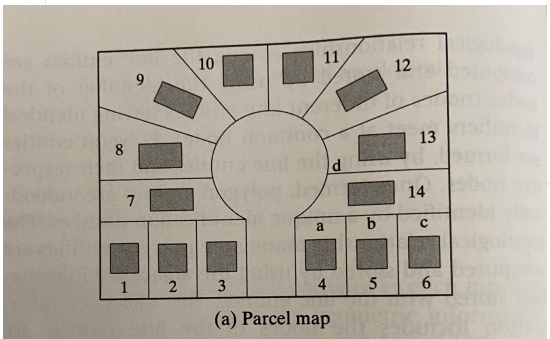
Topological Relationships: Areas of Usage

- Data input and representation
  - Identify and store adjacency, connectivity & containment information
    - field data collection, digitizing
    - E.g. Left/Right of polygon or line

Lo and Yeung (2006) Concepts and Techniques of Geographic Information Systems, Prentice Hall

6

6



(a) Parcel map

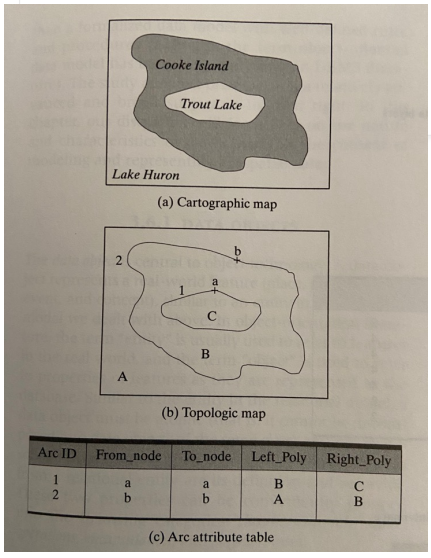
Arc ID	From_node	To_node	Left_Poly	Right_Poly
...				
...				
a			14	4
b			14	5
c			14	6
d			13	14
...				

(b) Arc attribute table

Topological Relationships: Areas of Usage

- Spatial Search by Topological Relationships
  - Find features by adjacency, containment and connectivity

7



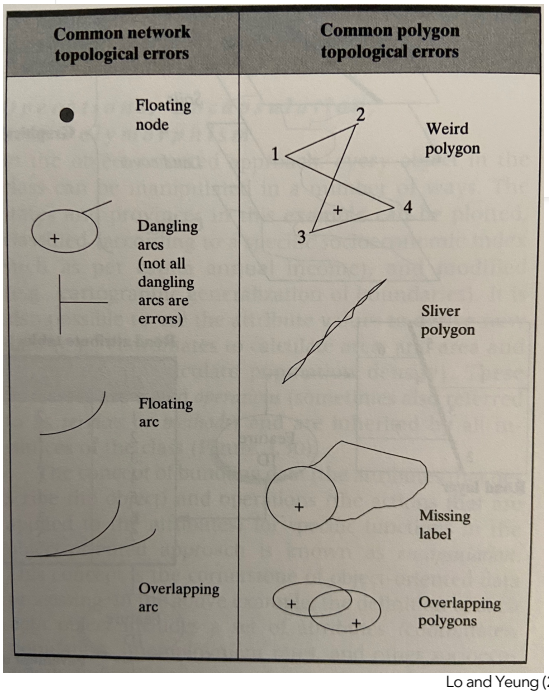
Arc ID	From_node	To_node	Left_Poly	Right_Poly
1	a	a	B	C
2	b	b	A	B

(c) Arc attribute table

Topological Relationships: Areas of Usage

- Construction of Complex Spatial Relationships
  - E.g. Holes on polygons
  - Multipart polygons

8



Topological Relationships: Areas of Usage

- Integrity checks and balances
  - Essentially the removal topological errors
    - E.g. No dangling arcs or overlapping polygons

Lo and Yeung (2006) Concepts and Techniques of Geographic Information Systems, Prentice Hall

9

9

Data Representation and Analysis

- Vector and Raster data models are ideally suited for solving different problems
  - Raster Model: phenomena that exhibit spatial variability
    - Temperature, topography
    - Environmental aspects at a regional or national scale
      - Habitat, biodiversity analysis, land cover

10

10

Data Representation and Analysis

- Vector and Raster data models are ideally suited for solving different problems
  - Vector Model: phenomena necessitates the need for location and individuality of spatial objects
    - Land title management, transportation management and planning, facilities management
    - Environmental aspects at a local scale (as opposed to a regional or national scale)

11

11

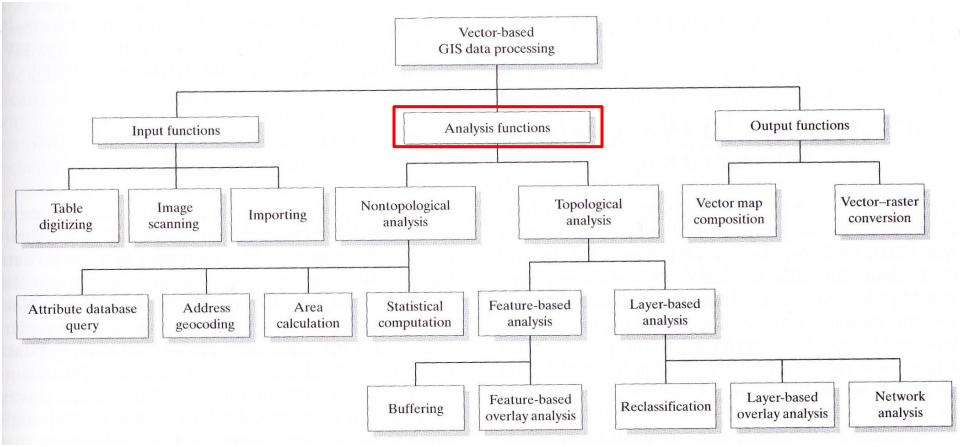
Spatial Analysis

- Analysis occurs using either:
  - **Spatial location** e.g. wetlands near a pipeline; houses within 5km
    - Distinguishes GIS from a non-spatial analysis
  - **Data attributes** e.g. wetlands with black spruce; houses in a given price range
    - Distinguishes GIS from 'non-GIS' mapping software
  - **Comparative spatial statistics**
    - e.g. the correlation of variables across space
    - e.g. wetlands clustered at local scale, uniform at regional scale
    - Statistical Spatial Data Analysis with ArcGIS, QGIS,….

12

12

Spatial Analysis



Source: C.P. Lo, A.K.W. Yeung (2007) Concepts and Techniques of Geographic Information Systems

13

13

Spatial Analysis

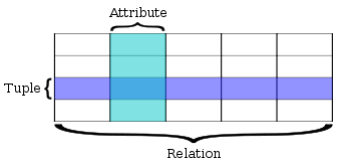
- Analysis functions
  - Non-topological functions
    - Attribute values of spatial data
  - Topological functions
    - Individual data objects
      - Feature-based
        - individual data objects
      - Layer-based
        - all objects in a layer

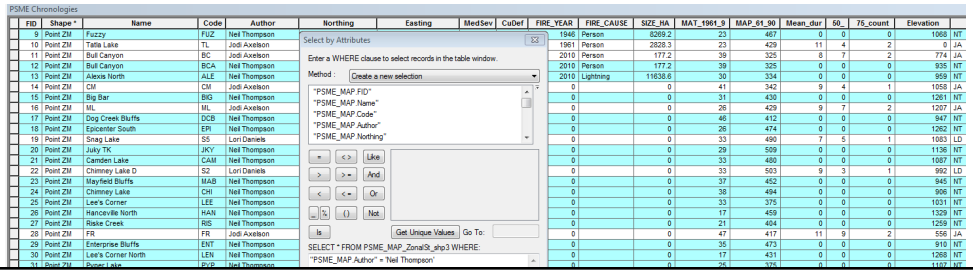
14

14

Nontopological Analysis

- SQL: Structured Query Language
- Goal: select only the features with (or without) particular values
- Relational table





15

Nontopological Analysis

- Attribute Database Query Operations
  - **SELECT**: Extract data items in specified rows of a table

    SELECT <attribute_name> FROM <table> WHERE <condition_statement>

  - **JOIN (RELATIONAL JOIN):** Merges two tables based on the values in the columns of the tables

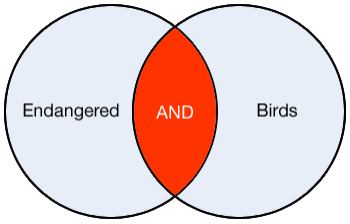
    [a select statement] *<table_1> JOIN <table_2> ON table_1.attribute= table_2.attribute*
    [a condition statement]

16

16

Nontopological Analysis

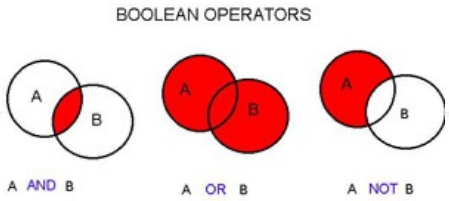
- **Boolean Logic** (after George Boole, a 19th century mathematician)
  - "Create an expression reducible to a true or false condition".
- **SQL can use:**
  - **Boolean Operators**
    - **And** (narrows the selection)
    - **Or** (expands the selection)
    - **Not** (excludes/reduces results)
    - **XOR** (A or B, but not both)
    - **Like (Similarity)**
      - **% is wildcard**



  - Relational Operators (=, >, <, >=, <=)
  - Arithmetic Operators (+, - *, /)

17

Boolean Operators (to combine conditions)



Selection by attribute

type = pine AND age > 100 ... selects all old growth pine

type = pine OR age > 100 selects all pine and any type older than 100

These may require the use of brackets to avoid ambiguity in complex queries e.g.

type = pine OR type = fir AND age > 100 selects any pine plus old growth fir

type = (pine OR type = fir) AND age > 100 selects old growth (pine and fir)

18

Nontopological Analysis

- Statistical Computation
  - Extension of attribute data query
  - Conventional statistical measures such as:
    - mean, maximum, minimum, range, standard deviation, frequency
    - Note: These are aspatial (non-spatial) statistics
    - Note: Can't do statistics on text field

19

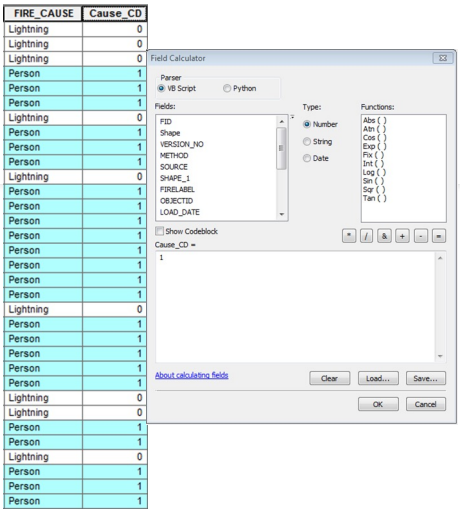
19

Nontopological Analysis

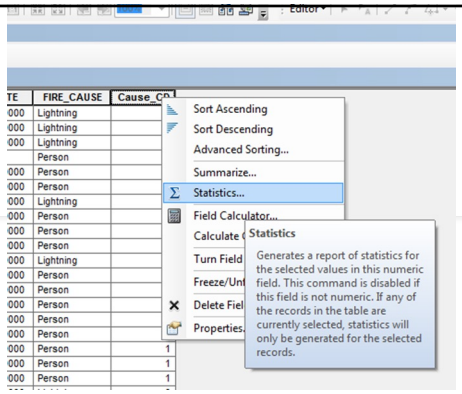
- Spatial Calculation
  - Spatial calculation of position, area, perimeter, distance, proximity
    - Algorithms are well known
  - An intermediate step to obtain new attribute data to support specific spatial analyses
  - Be sure that data are preprocessed
    - projection, coordinate transformation, measurement unit conversion

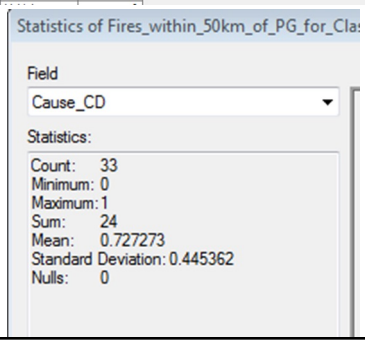
20

20



FIRE_CAUSE	Cause_CD
Lightning	0
Lightning	0
Lightning	0
Person	1
Person	1
Person	1
Lightning	0
Person	1
Person	1
Person	1
Lightning	0
Person	1
Person	1
Person	1
Person	1
Person	1
Person	1
Person	1
Lightning	0
Person	1
Person	1
Person	1
Person	1
Person	1
Lightning	0
Lightning	0
Person	1
Person	1
Lightning	0
Person	1
Person	1
Person	1



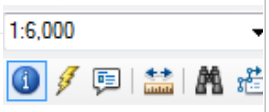


Statistics and the Field Calculator

21

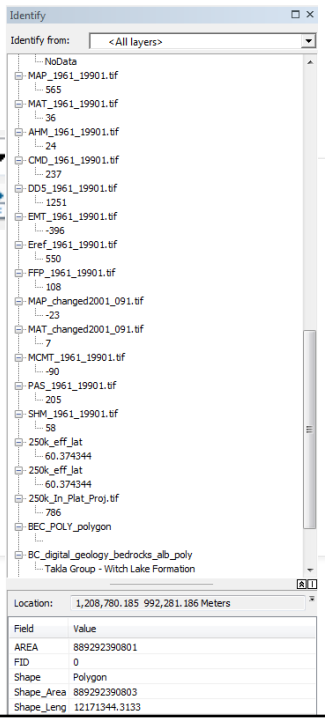
21

Selection in ArcGIS



- Manual selection
- By Location
- By Attributes

- Show attributes from
  - All layers
  - Selected layer
  - Visible layers
  - Top-most layer

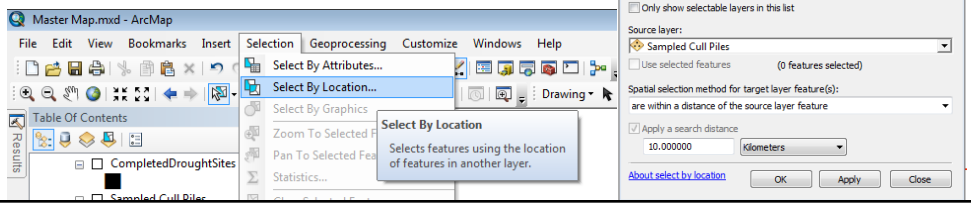


Once you have selected something, the selection will be all ArcGIS sees by default.
CAUTION when you export, analyze, compare

22

Select by Location

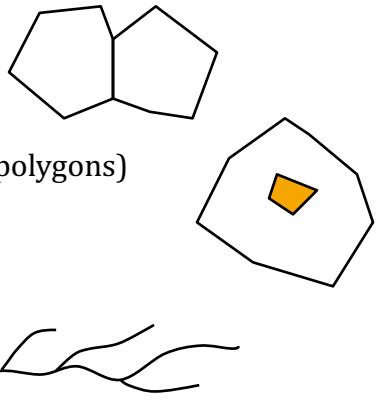
- Selects features from one data set based on their spatial relationship with another layer e.g.
  - Are within a distance of
  - Are within
  - Are completely within
  - Share a line segment with
  - Intersect



23

Topological Functions

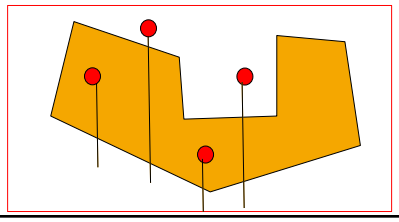
- Topology: spatial relationship between entities
  - Adjacency (polygons)
  - Containment (e.g. points in polygons)
  - Connectivity (lines)



24

Topological Functions

- Feature-Based Analysis: Find relationships between features of one layer and those of another
  - Common functions: Point in polygon, adjacency, connectivity, buffering
    - Point in polygon matching: whether a given point feature falls inside a polygon



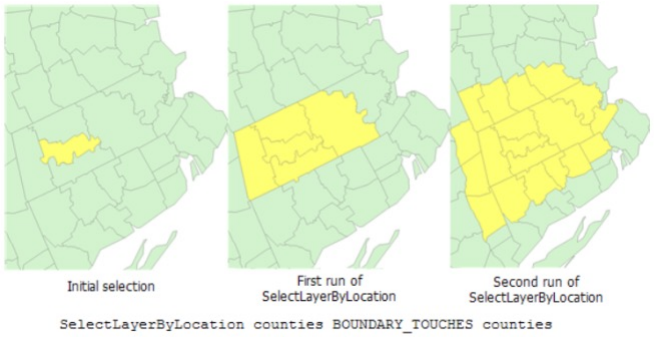
Plumb-line algorithm

Odd number of intersections: **In**
Even number of intersections: **Out**

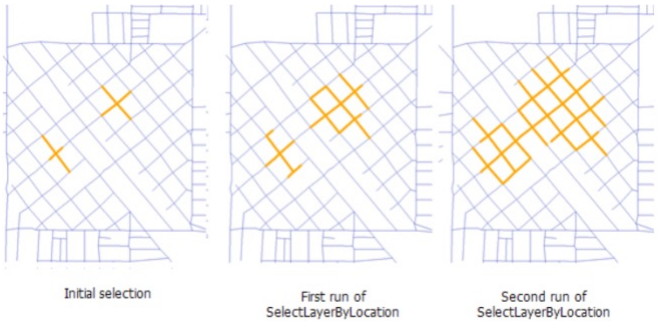
25

25

Touch = adjacency



Are connected with



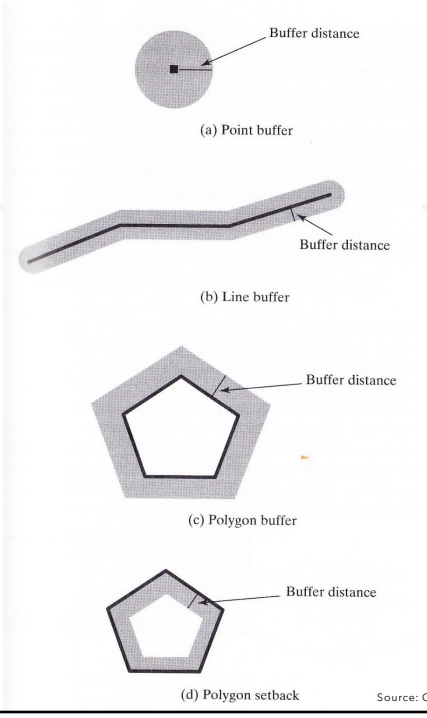
26

Topological Functions

- Buffering
  - A buffer is a zone covering a specified distance around a spatial feature
    - Buffer zones are polygons.
    - Buffer distance is usually user defined
    - Boundaries of overlapping buffer zones are automatically dissolved to give a single coherent buffer polygon

27

27



Useful when evaluating charactering of an area surrounding a feature.

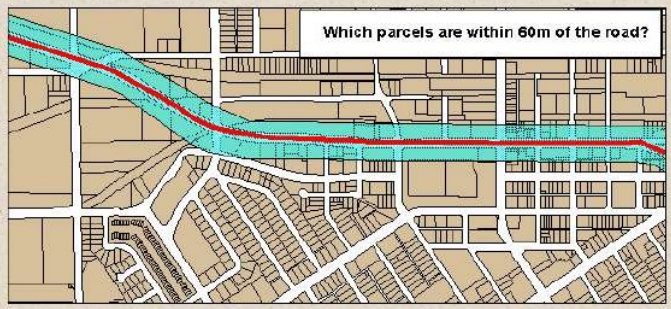
- properties/population with walking distance of a bus stop
- delineation of restricted zones around sensitive sites

Source: C.P. Lo, A.K.W. Yeung (2007) Concepts and Techniques of Geographic Information Systems

28

28

Applications of BUFFER

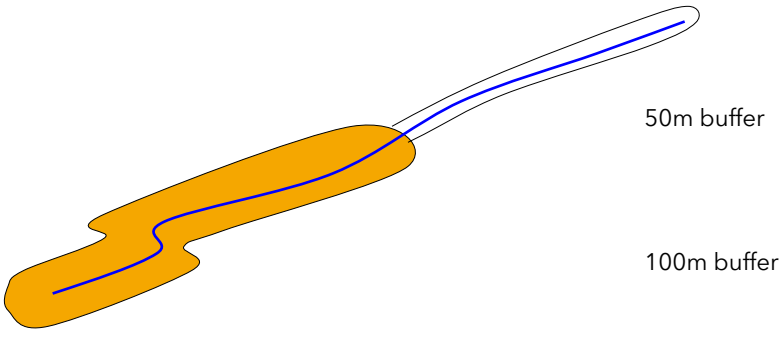


For example: consideration of widening of existing roadway, to identify parcels affected by underground utility line additions, etc.

29

Topological Functions

- *Variable buffer distances* (assigned by attribute)
  - Different buffer size depending on stream attribute
  - e.g. stream protection status



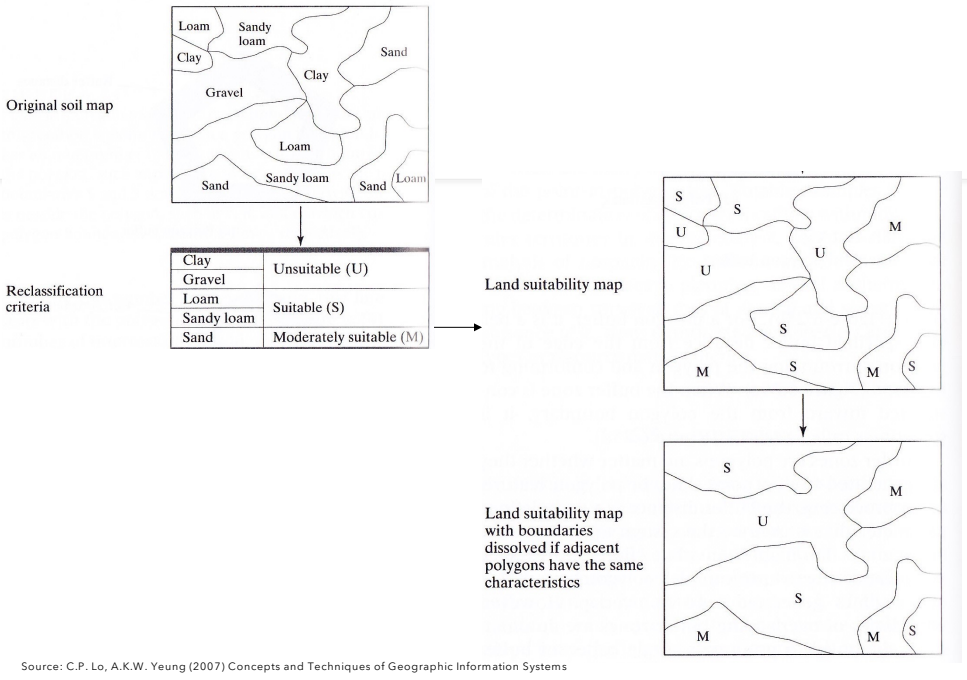
30

Topological Functions

- Reclassification
  - Database simplification process
    - reduces (modifies) the categories in attribute data
  - Two step process
    - Nontopological: select attribute e.g. a range of values and assign them a new class
    - Topological: dissolve according to new classification scheme

31

31



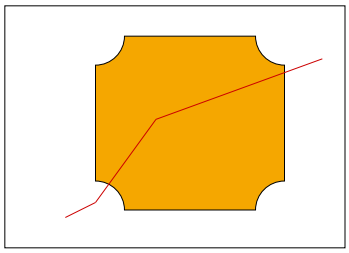
Source: C.P. Lo, A.K.W. Yeung (2007) Concepts and Techniques of Geographic Information Systems

32

32

The Concept of GIS Overlay

- Overlay addresses the relationship of the overlap between spatial features.
- Overlay combines the spatial *and* attribute data of two input themes.



Three input feature types, overlay cover is always polygon:

1) point-in-polygon, → points are output
2) line-in-polygon, → lines are output
3) polygon-in-polygon → polygons are output

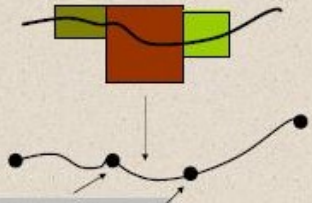
33

Line Feature Types and Map Overlay

- Line - in - Polygon

Input Theme

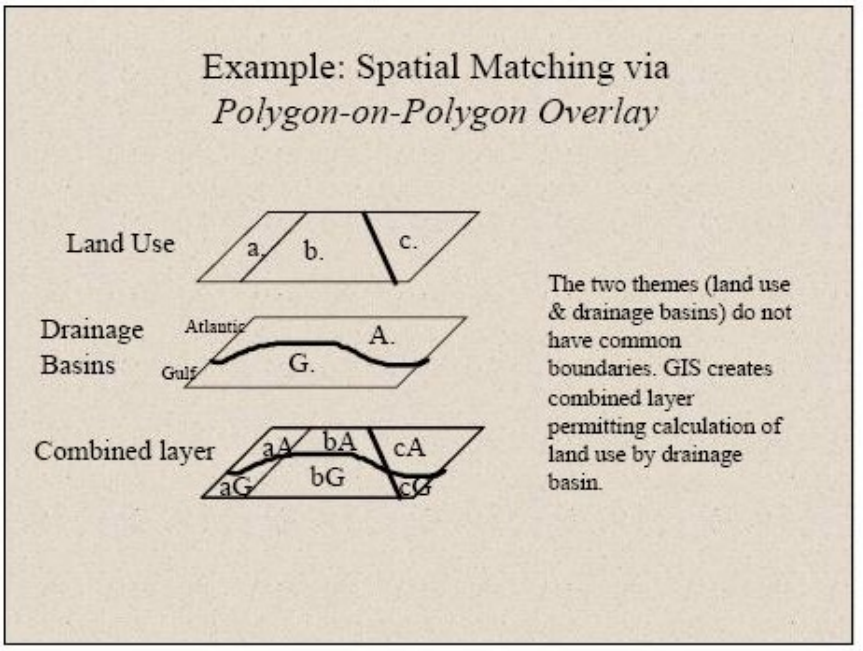
Overlay Theme



Two new intersections

- Attach attributes of polygon to line that traverses through polygon
- Example - What types of soils does a proposed road cross?
- Line is actually broken into different line segments at polygon boundaries. Each line segment takes on attributes for the polygon it overlays.

34



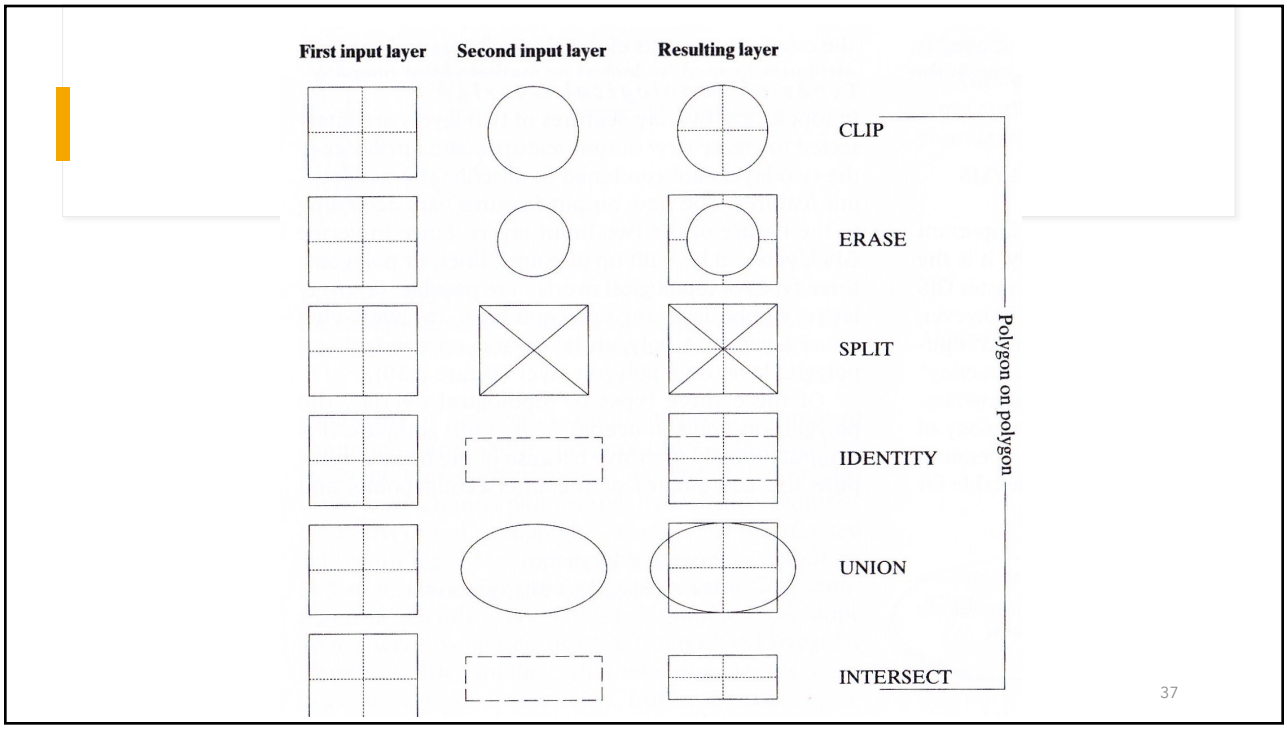
35

Topological Functions

- Topological Overlay Operators
  - UNION: Overlays polygons and keeps all areas in both layers. Never clips data
  - INTERSECT: Keeps portions of the first input layer that fall within the second input layer
  - IDENTITY: Overlays polygons and keeps all input features. The input features that overlap identity features will get the attributes of the identity features.
  - CLIP: Cuts out the first input layer using the second input layer as a cookie cutter
  - ERASE: Erases part of the first input layer using the second input layer
  - SPLIT: Divide the polygons in the first input layer into a number of smaller polygons based on the second input layer

36

36


First input layer
Second input layer
Resulting layer
CLIP
ERASE
SPLIT
IDENTITY
UNION
INTERSECT
Polygon on polygon
37

37