

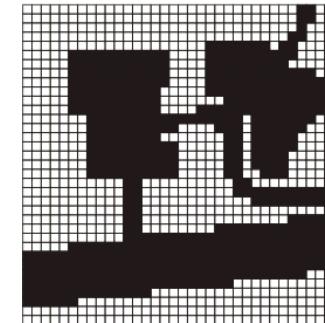
Spatial Analysis and Modeling (GIST 4302/5302)

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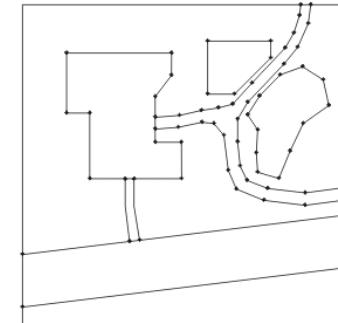
Representation of Spatial Data

Representation of Spatial Data Models

- **Object-based model:** treats the space as populated by discrete, identifiable entities each with a geospatial reference
 - Buildings or roads fit into this view
 - GIS Softwares: ArcGIS
- **Field-based model:** treats geographic information as collections of spatial distributions
 - Distribution may be formalized as a mathematical function from a spatial framework to an attribute domain
 - Patterns of topographic altitudes, rainfall, and temperature fit neatly into this view.
 - GIS Software: Grass



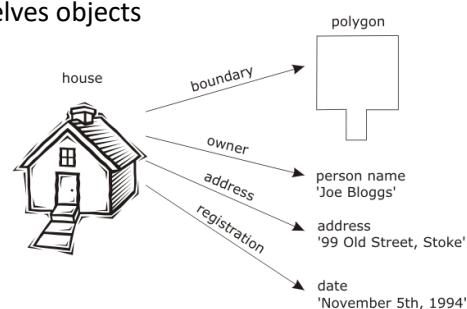
Raster



Vector

Object-based Approach

Has several attributes, such as registration date, address, owner and boundary, which are themselves objects



Entity

- Object-based models decompose an information space into objects or **entities**
- An entity must be:
 - Identifiable
 - Relevant (be of interest)
 - Describable (have characteristics)
- The frame of spatial reference is provided by the entities themselves

Example: House object

Attribute Tables

ID	Type	Value	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
3	Point	74	13	7.181452	70074	34.199444	-118.534722	-118.53472	34.19944
4	Point	75	13	6.076613	70075	34.066944	-117.751388	-117.75139	34.06694
5	Point	84	8	3.157258	70084	33.929167	-118.209722	-118.20972	33.92917
6	Point	85	11	5.201613	70085	34.015	-118.059722	-118.05972	34.015
7	Point	87	11	4.717742	70087	34.067222	-118.226389	-118.22639	34.06722
8	Point	88	15	6.532258	70088	34.083333	-118.106944	-118.10694	34.08333
9	Point	89	15	7.540323	70089	34.3875	-118.534722	-118.53472	34.3875
10	Point	91	10	4.891129	70091	34.050833	-118.454167	-118.45417	34.05083
11	Point	94	10	4.149194	70094	33.92357	-118.37085	-118.37085	33.92357
12	Point	96	13	7.266129	70096	34.69012	-118.1334	-118.1334	34.69012
13	Point	3176	9	4.100806	30176	33.820278	-117.9125	-117.9125	33.82028
14	Point	3177	10	4.737903	30177	33.926111	-117.951389	-117.95139	33.92611
15	Point	3186	11	4.600806	30186	33.6275	-117.690278	-117.69028	33.6275
16	Point	3195	8	4.358871	30195	33.67511	-117.9269	-117.9269	33.67511
17	Point	4137	13	8.241935	33137	33.85	-116.543056	-116.54306	33.85
18	Point	4144	17	8.794355	33144	34.010278	-117.426389	-117.42639	34.01028
19	Point	4149	15	8.899194	33149	33.708333	-117.243056	-117.24306	33.70833

Attribute Tables

- Basic operators on attribute tables
 - Selection:** picking certain rows
 - Projection:** picking certain columns
 - Join:** compositions of relations

Project Operator

- The **project** operator is unary
 - It outputs a new relation that has a subset of attributes
 - Identical tuples in the output relation are coalesced

Relation Sells:			Prices := PROJ _{beer,price} (Sells):	
bar	beer	price	beer	price
Chimy's	Bud	2.50	Bud	2.50
Chimy's	Miller	2.75	Miller	2.75
Cricket's	Bud	2.50	Miller	3.00
Cricket's	Miller	3.00		

Select Operator

- The **select** operator is unary
 - It outputs a new relation that has a subset of tuples
 - A condition specifies those tuples that are required

Relation Sells:

bar	beer	price
Chimy's	Bud	2.50
Chimy's	Miller	2.75
Cricket's	Bud	2.50
Cricket's	Miller	3.00

ChimyMenu := SELECT _{bar="Chimy's"} (Sells):		
bar	beer	price
Chimy's	Bud	2.50
Chimy's	Miller	2.75

Join Operator

- The **join** operator is binary
 - It outputs the combined relation where tuples agree on a specified attribute (natural join)

Sells(bar, beer, price)		Bars(bar, address)	
Chimy's	Bud	2.50	Chimy's 2417 Broadway St.
Chimy's	Miller	2.75	Cricket's 2412 Broadway St.
Cricket's	Bud	2.50	
Cricket's	Coors	3.00	

BarInfo := Sells JOIN Bars

Note Bars.name has become Bars.bar to make the natural join "work."

BarInfo(bar, beer, price, address)

Chimy's	Bud	2.50	2417 Broadway St.
Chimy's	Miller	2.75	2417 Broadway St.
Cricket's	Bud	2.50	2412 Broadway St.
Cricket's	Coors	3.00	2412 Broadway St.

Join Operator

- Join is the most time-consuming of all relational operators to compute
 - In general, relational operators may not be arbitrarily reordered (left join, right join)
 - Query optimization aims to find an efficient way of processing queries, for example reordering to produce equivalent but more efficient queries

Screenshot of a database query interface showing a table of data and a SQL query builder.

Table Data:

FID	Shape	STATION	MAXDAY	AV8TOP	MONITOR	LAT	LON	X_COORD	Y_COORD
0	Point	60	16	7.225806	70060	34.135833	-117.923611	-117.923611	34.135833
1	Point	69	14	5.899194	70069	34.176111	-116.315278	-116.315278	34.176111
2	Point	72	9	4.052685	70072	33.823611	-118.1875	-118.1875	33.823611
3	Point	74	13	7.181452	70074	34.199444	-116.534722	-116.534722	34.199444
4	Point	75	13	6.076613	70075	34.069444	-117.751389	-117.751389	34.069444
5	Point	84	8	3.157258	70084	33.929167	-116.209722	-116.209722	33.929167
6	Point	85	11	5.201613	70085	34.015	-116.059722	-116.059722	34.015
7	Point	87	11	4.771742	70087	34.067228	-116.283899	-116.283899	34.067228
8	Point	88	15	6.532258	70088	34.083333	-118.098444	-118.098444	34.083333
9	Point	89	15	7.540323	70089	34.3875	-116.534722	-116.534722	34.3875
10	Point	91	10	4.891129	70091	34.050833	-116.454167	-116.454167	34.050833
11	Point	94	10	4.149194	70094	33.82357	-118.370865	-118.370865	33.82357
12	Point	96	13	7.266129	70096	34.69012	-118.1334	-118.1334	34.69012
13	Point	3176	9	4.100006	30176	33.820278	-117.9125	-117.9125	33.820278
14	Point	3177	10	4.737903	30177	33.928111	-117.951389	-117.951389	33.928111
15	Point	3180	11	4.600006	30186	33.8275	-117.690278	-117.690278	33.8275
16	Point	3195	8	4.356871	30195	33.67511	-117.9269	-117.9269	33.67511
17	Point	4137	13	8.241935	33137	33.85	-116.543656	-116.543656	33.85
18	Point	4144	17	8.794555	33144	34.010278	-117.263899	-117.263899	34.010278
19	Point	4149	15	8.899194	33149	33.708333	-117.243556	-117.243556	33.708333
20	Point	4150	14	7.16129	33150	33.92	-116.876389	-116.876389	33.925
21	Point	4157	13	8.133695	33157	33.714555	-116.233898	-116.233898	33.714555
22	Point	4158	13	7.858071	33158	33.674041	-117.32114	-117.32114	33.674041
23	Point	4162	17	9.762097	33162	33.97562	-117.33265	-117.33265	33.97562
24	Point	5175	16	8.149194	36175	34.103611	-117.289167	-117.289167	34.103611
25	Point	5181	22	11.649194	36181	34.243884	-117.273611	-117.273611	34.243884
26	Point	5197	17	8.604639	36197	34.099444	-117.504167	-117.504167	34.099444
27	Point	5203	20	9.947581	36203	34.107222	-117.273611	-117.273611	34.107222
28	Point	5204	19	10.274194	36204	34.066667	-117.15139	-117.15139	34.066667
29	Point	5212	17	8.524194	36512	33.8846	-117.512733	-117.512733	33.8846
30	Point	5213	9	4.447917	36513	34.262276	-117.198543	-117.198543	34.262276
31	Point	591	18	8.241935	70591	34.143869	-117.851389	-117.851389	34.143869

Select By Attributes:

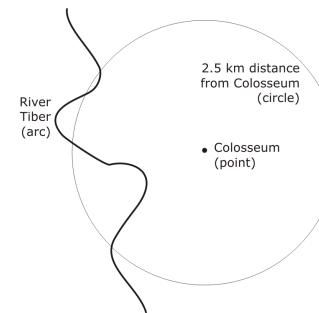
```
Layer: o296
Method: Create a new selection
"STATION"
"MAXDAY"
"AV8TOP"
"MONITOR"
"LAT"
```

SQL Query:

```
SELECT * FROM o296 WHERE
MAXDAY >=
```

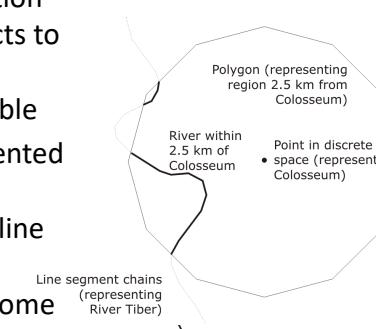
Example: GIS analysis

- For Italy's capital city, Rome, calculate the total length of the River Tiber which lies within 2.5 km of the Colosseum
 - First we need to model the relevant parts of Rome as objects
 - Operation **length** will act on **arc**, and **intersect** will apply to form the piece of the **arc** in common with the disc



Example: GIS analysis

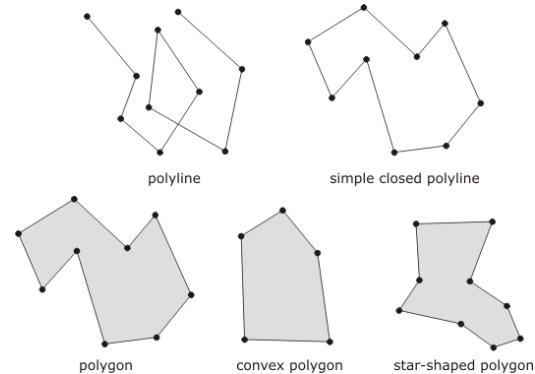
- A process of discretization must convert the objects to types that are computationally tractable
- A circle may be represented as a discrete polygonal area, arcs by chains of line segments, and points may be embedded in some discrete space



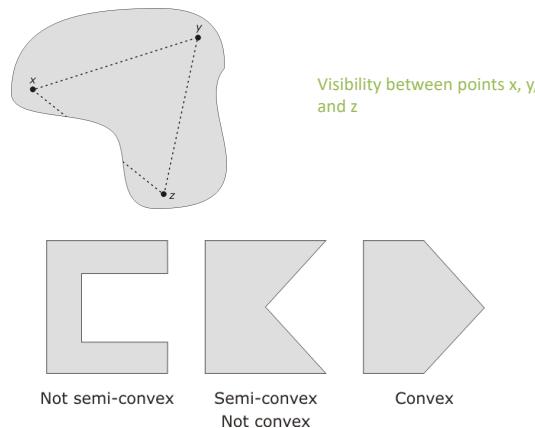
Primitive Objects

- **Euclidean Space:** coordinatized model of space
 - Transforms spatial properties into properties of tuples of real numbers
 - Coordinate frame consists of a fixed, distinguished point (origin) and a pair of orthogonal lines (axes), intersecting in the origin
- Point objects, a coordinate pair or vector (x, y)
- Line objects, a string of points
- Polygonal objects

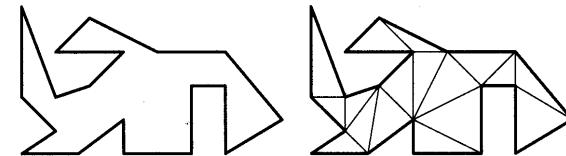
Polygonal objects



Convexity

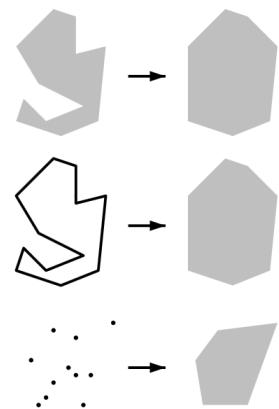
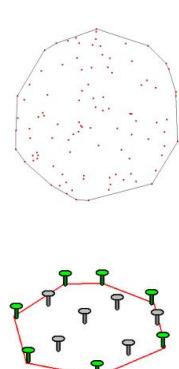


Example: Triangulation

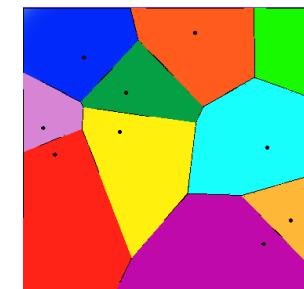


- Every simple polygon has a triangulation. Any triangulation of a simple polygon with n vertices consists of exactly $n - 2$ triangles
- Art Gallery Problem
 - How many cameras are needed to guard a gallery and how should they be placed?
 - Upper bound $N/3$

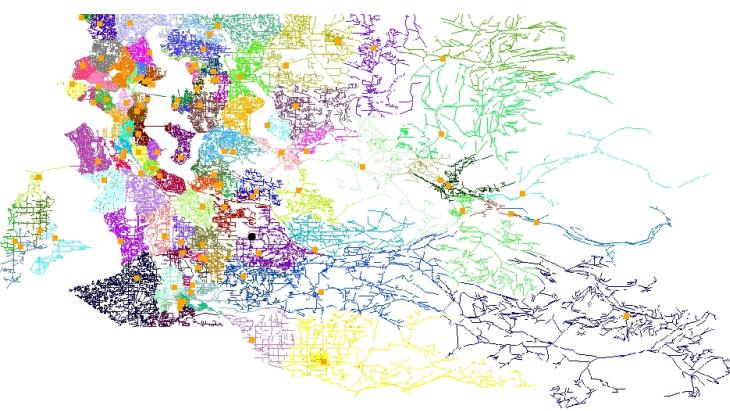
Related: Convex Hull



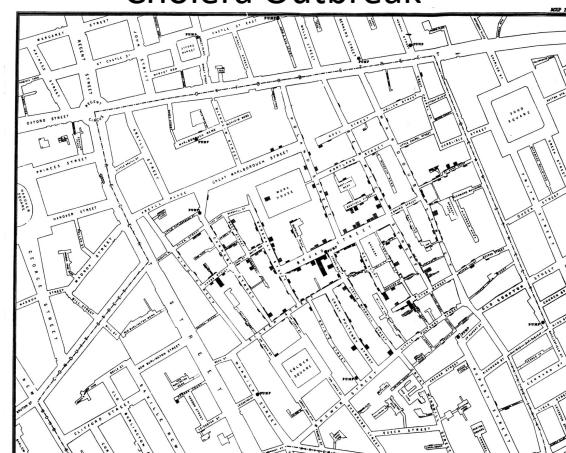
Related: Voronoi Diagram

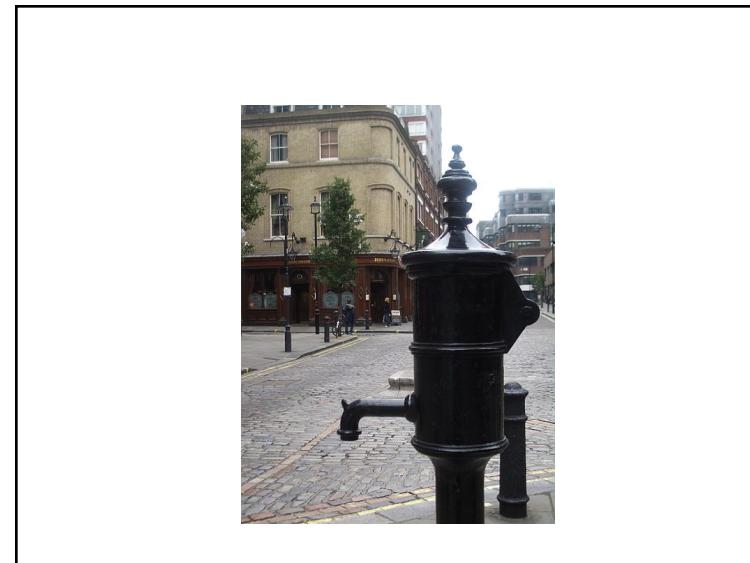


Voronoi Diagram on Road Network



John Snow, Pumps and Cholera Outbreak



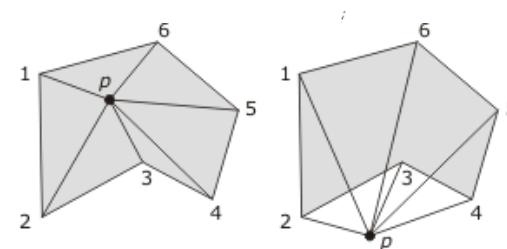


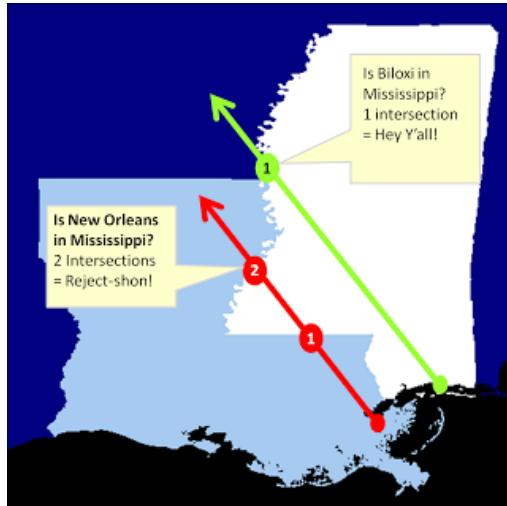
Primitive GIS Operations

- in Euclidean spaces
 - Length, bearing, area
 - How many ways you can think of to calculate the area of a polygon?
 - How to test which side of a point corresponding to a line?
 - Distance between objects (points, lines, polygons)
 - Distance could be ambiguous, e.g., what is the difference from Lubbock to Dallas (from city center or city boundary?).
 - Centroid
 - Not necessarily within in the boundary of polygon
 - Point in polygon
 - Ray casting method
 - Point on line
 - area
 - Buffer
 - Intersection/overlay
- In topological spaces
 - Spatial relations (within, touch, cover, ...)

Point in polygon

- Determining whether a point is inside a polygon is one of the most fundamental operations in a spatial database
- **Semi-line method (ray casting)** : checks for odd or even numbers of intersections of a semi-line with polygon
- **Winding method**: sums bearings from point to polygon vertices





Primitive GIS operations: Overlay

- Union
- Intersect
- Erase
- Identity
- Update
- Spatial Join
- Symmetrical Difference

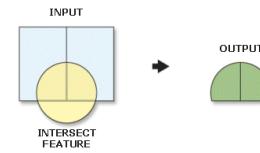
Overlay

- Union
 - Computes a geometric union of the input features. All features and their attributes will be written to the output feature class.



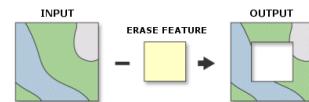
Overlay

- Intersect
 - Computes a geometric intersection of the input features. Features or portions of features which overlap in all layers and/or feature classes will be written to the output feature class.



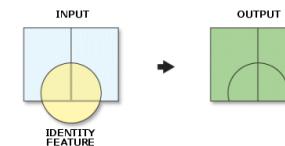
Overlay

- Erase
 - Creates a feature class by overlaying the Input Features with the polygons of the Erase Features. Only those portions of the input features falling outside the erase features outside boundaries are copied to the output feature class



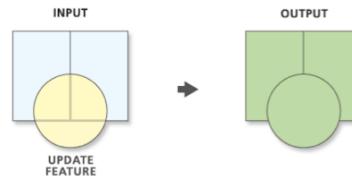
Overlay

- Identity
 - Computes a geometric intersection of the input features and identity features. The input features or portions thereof that overlap identity features will get the attributes of those identity features



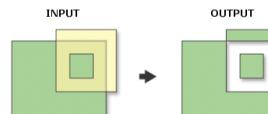
Overlay

- Update
 - Computes a geometric intersection of the Input Features and Update Features. The attributes and geometry of the input features are updated by the update features in the output feature class.



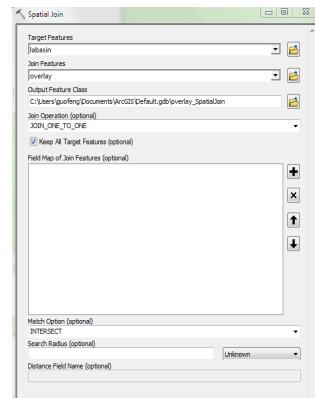
Overlay

- Symmetrical difference
 - Features or portions of features in the input and update features that do not overlap will be written to the output feature class.



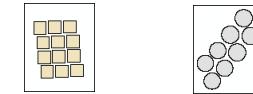
Overlay

- **Spatial join**
 - Joins attributes from one feature to another based on the spatial relationship. The target features and the joined attributes from the join features are written to the output feature class.

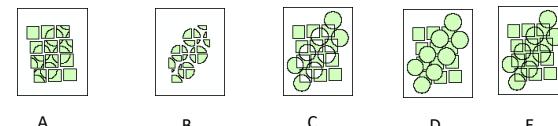


Quiz

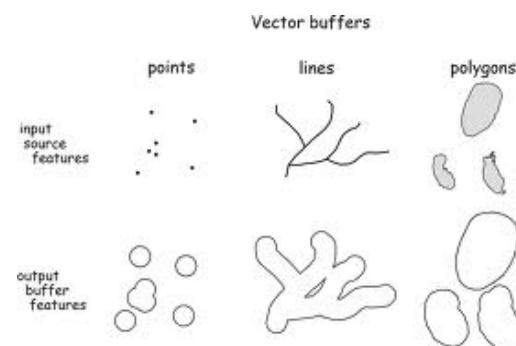
Input Feature Overlay Feature



Which of the following is the result of identity, intersect, symmetrical difference, union and update respectively?



Buffer



• Primitive operators

- you might already realized that these primitive operators are often used collaboratively with each other, and other analytical methods (e.g., dissolve, surface analysis, interpolation) that we will introduce in the coming lectures.

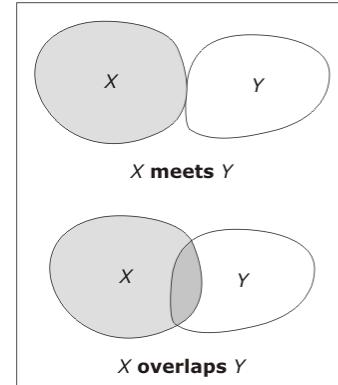
Topological spatial operations: spatial relationship

- Object types with an assumed underlying topology are **point**, **arc**, **loop** and **area**
- Operations:
 - boundary**, **interior**, **closure** and **connected** are defined in the usual manner
 - components** returns the set of maximal connected components of an area
 - extremes** acts on each object of type arc and returns the pair of points of the arc that constitute its end points
 - is within** provides a relationship between a point and a simple loop, returning true if the point is enclosed by the loop

Topological spatial operations for areas

– **X meets Y** if X and Y touch externally in a common portion of their boundaries

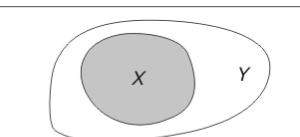
– **X overlaps Y** if X and Y impinge into each other's interiors



X is not **disjoint from Y**

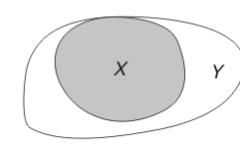
Topological spatial operations for areas

– **X is inside Y** if X is a subset of Y and X, Y do not share a common portion of boundary



X is inside Y

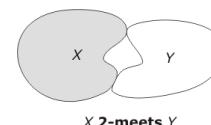
– **X covers Y** if Y is a subset of X and X, Y touch externally in a common portion of their boundaries



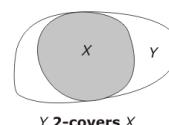
X is a **subset of Y**

Topological spatial operations

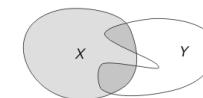
- There are an infinite number of possible topological relationships that are available between objects of type cell



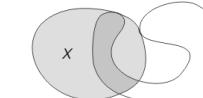
X 2-meets Y



Y 2-covers X



X 2-overlaps Y



Match Option (optional)
CONTAINS_CLEMENTINI
INTERSECT
INTERSECT_3D
WITHIN_A_DISTANCE
WITHIN_A_DISTANCE_3D
CONTAINS
COMPLETELY_CONTAINS
CONTAINS_CLEMENTINI
WITHIN
COMPLETELY_WITHIN
WITHIN_CLEMENTINI
ARE_IDENTICAL_TO
BOUNDARY_TOUCHES
SHARE_A_LINE_SEGMENT_WITH
CROSSED_BY_THE_OUTLINE_OF
HAVE THEIR_CENTER_IN
CLOSEST

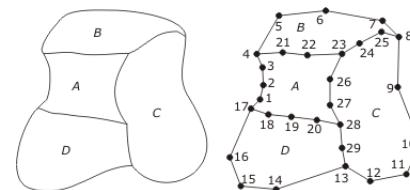
http://resources.esri.com/help/9.3/ArcGISDesktop/com/Gp_ToolRef/Data_Management_toolbox/select_by_location_colon_graphical_examples.htm

- Contain vs CONTAINS_CLEMENTINI:
 - the results of CONTAINS_CLEMENTINI will be identical to CONTAINS with the exception that if the feature in the Selecting Features layer is entirely on the boundary of the Input Feature Layer, with no part of the contained feature properly inside the feature in the Input Feature Layer, the input feature will not be selected.

- Graphical examples:
 - http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?topicname=select_by_location:graphical_examples

Spaghetti

- Spaghetti** data structure represents a planar configuration of points, arcs, and areas
- Geometry is represented as a set of lists of straight-line segments



Spaghetti- example

- Each polygonal area is represented by its boundary loop
- Each loop is discretized as a closed polyline
- Each polyline is represented as a list of points

A:[1,2,3,4,21,22,23,26,27,28,20,19,18,17]

B:[4,5,6,7,8,25,24,23,22,21]

C:[8,9,10,11,12,13,29,28,27,26,23,24,25]

D:[17,18,19,20,28,29,13,14,15,16]

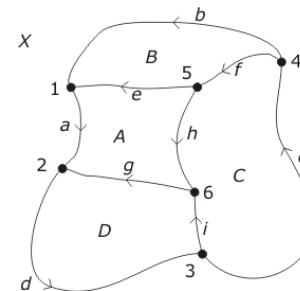
Issues

- There is **NO** explicit representation of the topological interrelationships of the configuration, such as adjacency
- Data consistence issues
 - *Silver polygons*
 - *Data redundancy*

NAA: node arc area

- Each directed arc has exactly one start and one end node.
- Each node must be the start node or end node (maybe both) of at least one directed arc.
- Each area is bounded by one or more directed arcs.
- Directed arcs may intersect only at their end nodes.
- Each directed arc has exactly one area on its right and one area on its left.
- Each area must be the left area or right area (maybe both) of at least one directed arc.

NAA: planar decomposition



Arc	Begin	End	Left	Right
a	1	2	A	X
b	4	1	B	X
c	3	4	C	X
d	2	3	D	X
e	5	1	A	B
f	4	5	C	B
g	6	2	D	A
h	5	6	C	A
i	3	6	D	C

Field-based Approach

Spatial fields

- If the spatial framework is a Euclidean plane and the attribute domain is a subset of the set of real numbers;
 - The Euclidean plane plays the role of the horizontal xy-plane
 - The ***spatial field*** values give the z-coordinates, or “heights” above the plane

Regional Climate Variations

Imagine placing a square grid over a region and measuring aspects of the climate at each node of the grid. Different fields would then associate locations with values from each of the measured attribute domains.

Properties of the attribute domain

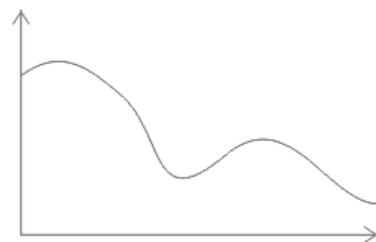
- The attribute domain may contain values which are commonly classified into four levels of measurement
 - **Nominal attribute**: simple labels; qualitative; cannot be ordered; and arithmetic operators are not permissible
 - **Ordinal attribute**: ordered labels; qualitative; and cannot be subjected to arithmetic operators, apart from ordering
 - **Interval attributes**: quantities on a scale without any fixed point; can be compared for size, with the magnitude of the difference being meaningful; the ratio of two interval attributes values is not meaningful
 - **Ratio attributes**: quantities on a scale with respect to a fixed point; can support a wide range of arithmetical operations, including addition, subtraction, multiplication, and division

Continuous and differentiable fields

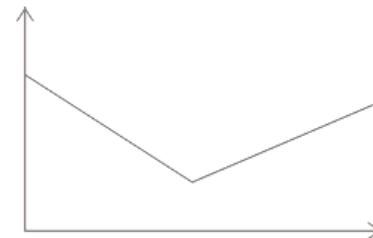
- **Continuous** field: small changes in location leads to small changes in the corresponding attribute value
- **Differentiable** field: rate of change (slope) is defined everywhere
- Spatial framework and attribute domain must be continuous for both these types of fields
- Every differentiable field must also be continuous, but not every continuous field is differentiable

One dimensional examples

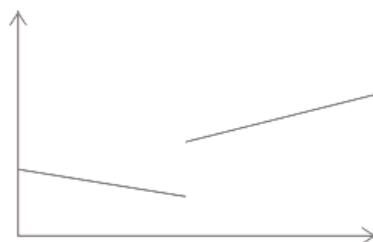
- Fields may be plotted as a graph of attribute value against spatial framework



One dimensional examples

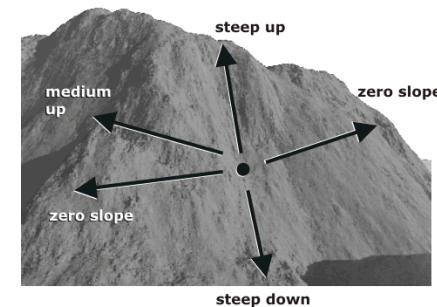


One dimensional examples



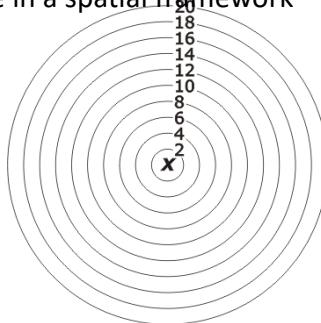
Two dimensional examples

- The slope is dependent on the particular location and on the bearing at that location



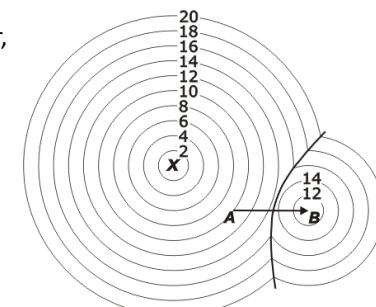
Isotropic fields

- A field whose properties are independent of direction is called an **isotropic field**
- Consider travel time in a spatial framework
 - The time from X to any point Y is dependent only upon the distance between X and Y and independent of the bearing of Y from X



Anisotropic fields

- A field whose properties are dependent on direction is called an **anisotropic field**.
- Suppose there is a high speed link AB
 - For points near B it would be better, if traveling from X, to travel to A, take the link, and continue on from B to the destination
 - *The direction to the destination is important*

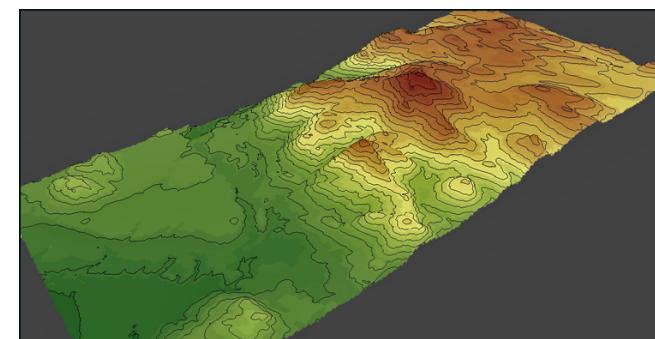


Representations of Spatial Fields

- Points
- Contours
- Raster/Lattice
- Triangulation (Delaunay Triangulation)

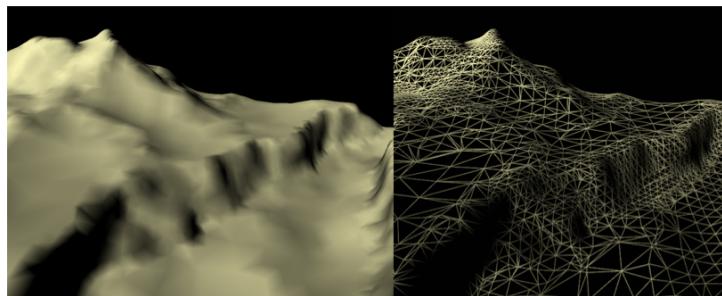
Example

- Contour lines and raster



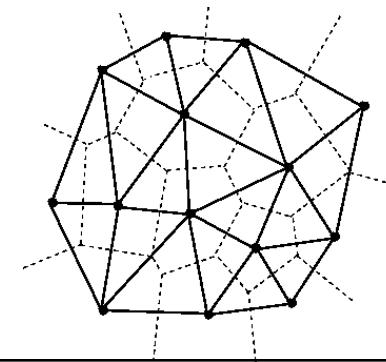
Example

- Triangulations



Side Note: Delaunay Triangulation and Voronoi Diagram

- Dual Graph

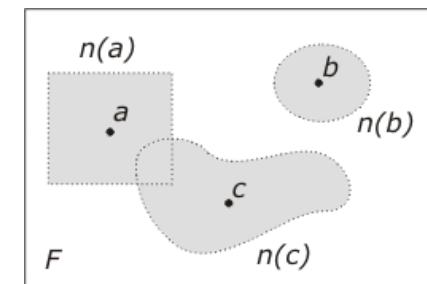


Operations on fields

- A field operation takes as input one or more fields and returns a resultant field
- The system of possible operations on fields in a field-based model is referred to as *map algebra*
- Three main classes of operations
 - Local
 - Focal
 - Zonal

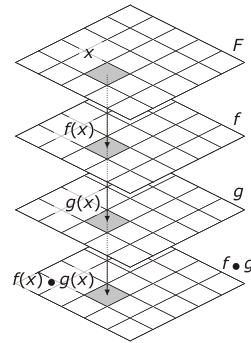
Neighborhood function

- Given a spatial framework F , a **neighborhood function** n is a function that associates with each location x a set of locations that are “near” to x



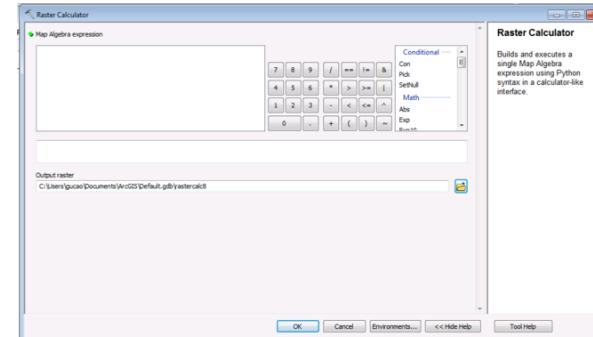
Local operations

- **Local operation:** acts upon one or more spatial fields to produce a new field
- The value of the new field at any location is dependent on the values of the input field function at that location
 - is any binary operation



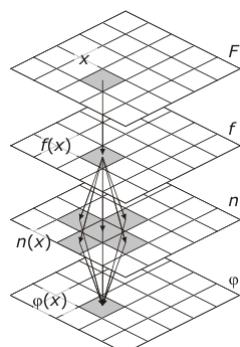
Local operations

- Typical operations:
 - Raster calculator



Focal operations

- **Focal operation:** the attribute value derived at a location x may depend on the attributes of the input spatial field functions at x and the attributes of these functions in the neighborhood $n(x)$ of x

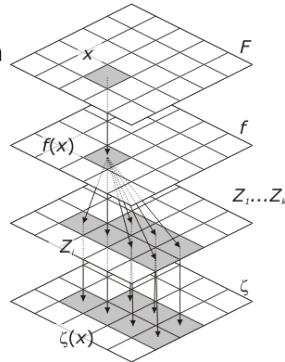


Focal operations

- Typical operations:
 - Slope
 - Aspect
 - Hill shade
 - Focal statistics

Zonal operations

- **Zonal operation:** aggregates values of a field over a set of zones (arising in general from another field function) in the spatial framework
- For each location x :
 - ◆ Find the Zone Z_i in which x is contained
 - ◆ Compute the values of the field function f applied to each point in Z_i
 - ◆ Derive a single value $\zeta(x)$ of the new field from the values computed in step 2

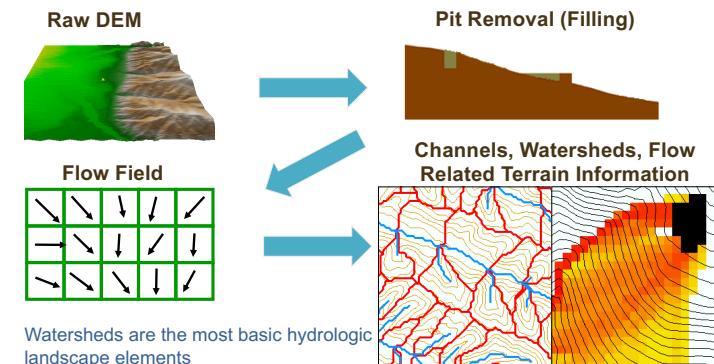


Zonal operations

- Typical operations:
 - Zonal
 - Viewshed
 - Watershed

More on Watershed Analysis

The terrain flow **information model** for deriving channels, watersheds, and flow related terrain information.



Courtesy of Dr. David G. Tarboton

The Pit Removal Problem



- DEM creation results in **artificial pits** in the landscape
- A pit is a set of one or more cells which has **no downstream cells** around it
- Unless these pits are removed they become **sinks** and isolate portions of the watershed
- Pit removal** is first thing done with a DEM

Pit Filling



Increase elevation to the pour point elevation until the pit drains to a neighbor

Pit Filling

Original DEM

7	7	6	7	7	7	7	5	7	7
9	9	8	9	9	9	9	7	9	9
11	11	10	11	11	11	11	9	11	11
12	12	8	12	12	12	12	10	12	12
13	12	7	12	13	13	13	11	13	13
14	7	6	11	14	14	14	12	14	14
15	7	7	8	9	15	15	13	15	15
15	8	8	8	7	16	16	14	16	16
15	11	11	11	11	17	17	6	17	17
15	15	15	15	15	18	18	15	18	18

Pits

Grid cells or zones completely surrounded by higher terrain

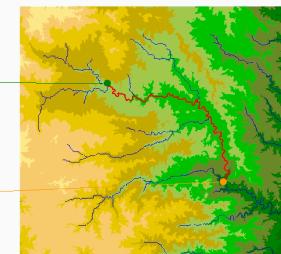
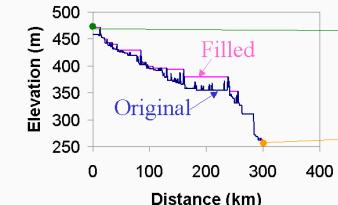
Pits Filled

7	7	6	7	7	7	7	5	7	7
9	9	8	9	9	9	9	7	9	9
11	11	10	11	11	11	11	9	11	11
12	12	10	12	12	12	12	10	12	12
13	12	10	12	13	13	13	11	13	13
14	10	10	11	14	14	14	12	14	14
15	10	10	10	10	15	15	13	15	15
15	11	11	11	11	17	17	14	17	17
15	15	15	15	15	18	18	15	18	18

Pour Points

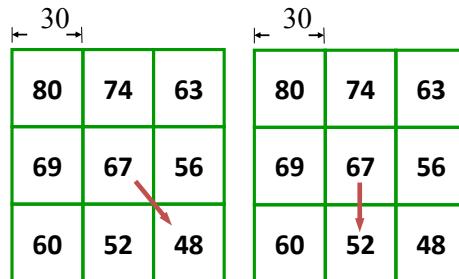
The lowest grid cell adjacent to a pit

Effect of Pit Filling on Elevation



Hydrologic Slope

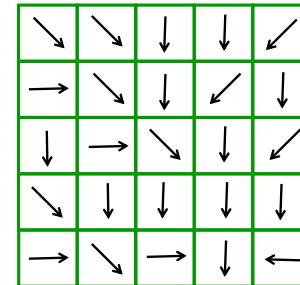
- Direction of Steepest Descent



$$\text{Slope: } \frac{67 - 48}{30\sqrt{2}} = 0.45 \quad \boxed{\frac{67 - 52}{30} = 0.50}$$

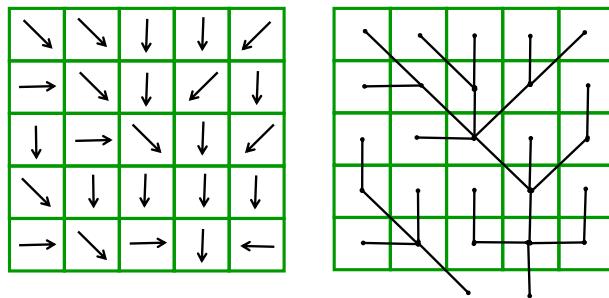
Eight Direction (D8) Flow Model

32	64	128
16		1
8	4	2



2	2	4	4	8
1	2	4	8	4
4	1	2	4	8
2	4	4	4	4
1	2	1	4	16

Grid Network



Flow Accumulation Grid. Area draining **in** to a grid cell

0	0	0	0	0
0	2	2	2	0
0	0	10	0	1
1	0	0	14	0
0	4	1	19	1

0	0	0	0	0
0	2	2	2	0
0	0	10	0	1
1	0	0	14	0
0	4	1	19	1

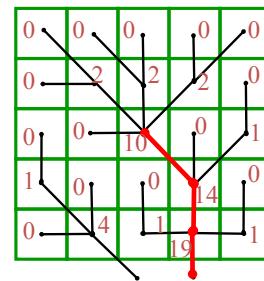
[Link](#) to Grid calculator

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Flow Accumulation
> 10 Cell Threshold

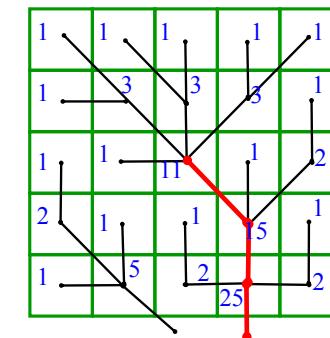
0	0	0	0	0
0	2	2	2	0
0	0	10	0	1
1	0	0	14	0
0	4	1	19	1

Stream Network for
10 cell Threshold
Drainage Area



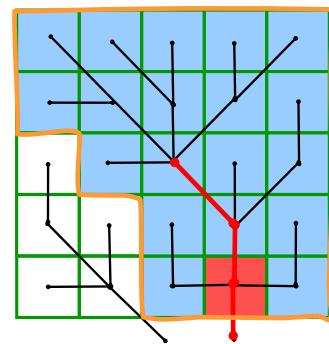
TauDEM contributing area convention.

1	1	1	1	1
1	3	3	3	1
1	1	11	1	2
2	1	1	15	1
1	5	2	20	2



The area draining each grid cell includes the
grid cell itself.

Watershed Draining to Outlet



Summary of Key Processing Steps

- [DEM Reconditioning]
- Pit Removal (Fill Sinks)
- Flow Direction
- Flow Accumulation
- Stream Definition
- Stream Segmentation
- Catchment Grid Delineation
- Raster to Vector Conversion (Catchment Polygon, Drainage Line, Catchment Outlet Points)

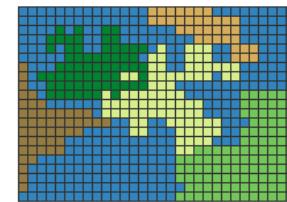
Summary Concepts

- The eight direction pour point model approximates the surface flow using eight discrete grid directions
- The elevation surface represented by a grid digital elevation model is used to derive surfaces representing other hydrologic variables of interest such as
 - Slope
 - Flow direction
 - Drainage area
 - Catchments, watersheds and channel networks

Summary: Object-based vs Field-based models



Polygon features



Raster polygon features

From:

http://resources.arcgis.com/en/help/main/10.2/index.html#/How_features_are_represented_in_a_raster/009t0000000600000/

Summary: Object-based vs Field-based models

- Object-based models:
 - Greater precision
 - Less redundant information (smaller storage footprints)
 - Complex data structures
- Field-based models:
 - Simpler data structures
 - More redundant information (larger storage footprints)
 - Less precision
- *Raster is faster, but vector is corrector*

Raster <-> Vector

- Vector-> Raster
 - Interpolation
 - Inverse distance weighted, Kriging, Spline
 - Density surface
 - Kernel density
 - Rasterization
- Raster->Vector
 - Watershed
 - Vectorization (raster to polygon)
 - ...

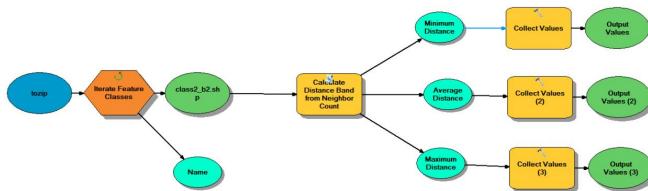
Model Builder

Model Builder

- Model Builder is a drag-and-drop interface to ArcToolbox called ModelBuilder allowing you to develop a flow chart of your GIS workflow
 - This flowchart is then run step by step to perform your analysis
- ArcGIS allows for custom scripting that can be added to ArcToolbox, introducing greater functionality
 - Custom export scripts, specialized versions of existing tools, develop tools not available in ArcToolbox

Model Builder

- Graphic Programming



Why Model Builder?

- Developing a model for a GIS analysis allows for repeat testing of a hypothesis using different data.
- The model can be coded into a GIS application, so that the steps are performed automatically.
- Easier reproduction of results.
- Simplification of workflow.
- Informs the computer how to conduct a series of steps that would be impractical for you to do manually.

Reproducibility

- In performing an analysis, you must have your workflow clearly defined.
- This ensures that you are performing the steps in the correct order using the appropriate tools.
- Missteps are easy, especially when there can be hours of computer processing between steps.
- The GIS model can be exported as a graphic flowchart or a modeling data structure.

Workflow Efficiency

- There are many repetitive steps you will take in your daily workflow.
- Streamlining the process saves you time.
- If you always start working in a File Geodatabase with specific resolution and projection information, a model for generating your specialized GDB can be created.

Human Inefficiency

- You physically cannot perform the steps as fast as GIS can produce the results.
- Certain steps, such as iteration through a feature set would be prohibitively time consuming.
- Minimize the amount of time spent “babysitting” GIS to perform complex analyses.

Inside ArcToolbox

Icon	Name	Description
	Toolset	A container for organizing the contents of a toolbox.
	Tool	Runs an underlying function in the geoprocessing framework.
	Script	Can be written in any Common Object Model (COM)-compliant scripting language, such as Python, JScript, or VBScript. An ArcInfo Workstation ARC Macro Language (AML) can also be added to a toolbox as a script.
	Model	You can view and edit these in the new integrated ModelBuilder window.

Demo

- Demo
- Lab: Buffalo commons using Model Builder:

