Introduktion till dataanalys i GIS

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Föreläsningens innehåll och syfte

Föreläsningen ger en introduktion till analyser i Geografiska Informationssystem

- Rumsliga analyser
  - Geometriska vektoranalyser
  - Nätverk
  - Nätverksanalys med vektorer
  - “Data mining”

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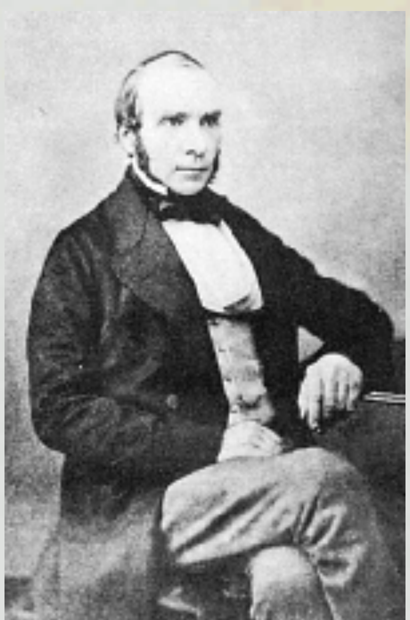
Rumsliga analyser

First attempt of visual analysis of spatial data: **Dr. Snow's map of cholera outburst in London, 1855**



Rumsliga analyser

- Lokal (punkt)
- Fokal (grannar)
- Regional (nätverk)

- Profildata (2D, 2.5D, 3D)

- Tidsserier

Rumsliga analyser

- Frågor (queries)
- Mätningar
- Transformationer
- Deskriptiva metoder
- Optimering
- Hypotesprövning

Rumsliga analyser …

- Can handle the multiple perspectives of doing science
  - Constructive/Inductive or Positivist/Deductive
    - Either build theory or test theory
    - Ultimately for a normative purpose – best, good, ideal based on your value system
  - Mode II or Post-Normal too
    - Problem solving with transdisciplinary approach
  - Qualitative or Quantitative
    - Verbal descriptions, Quantitative ability
    - In database fields – vector
    - In grid values - raster

Rumsliga analyser

- In essence GIS can handle any model that you can conceive that uses attribute, spatial, and temporal components
- You've done a lot of it already in your labs!
  - Exploration of spatial data, measurements, sampling representation, mapping, evaluation, overlay multiply, overlay site analysis, watersheds and pollution susceptibility, land use and cover change
- Some processes change or create new data, others just use the data as is
- Again, all of this is to build information to help solve your problem, support your decision making, and aid your research
- **You** determine its value and how that information is used!!!!
- Finally, we should be thinking of the output or deliverables
  - NOT JUST MAPS!
  - For some results of analysis it may be more appropriate to use report/memo, charts, and/or tables, simulation videos

Exploration and Queries

- Exploration and Mapping of existing data – just examining the variables in question from viewing the data
  - In essence simple and superficial query
  - No real GIS operations except displaying the tables and/or map display, turning layers "on" or "off"
  - Symbolization and Cartography may be more important
- Queries answer questions based on existing data
  - No new data generated and existing data is not revised
    - But may be temporarily and then eventually permanently manipulated to pull together all necessary data (e.g. new table creation, or subset of spatial data selected)

Query

- Two basic questions
  - What is where – Query by location
  - Where is what – Query by attribute
  - Those are the two “basic” questions, but I can get more complex with my query
- In GIS we can query by using map display, tables, or catalogs (databases)

Rumsliga analyser

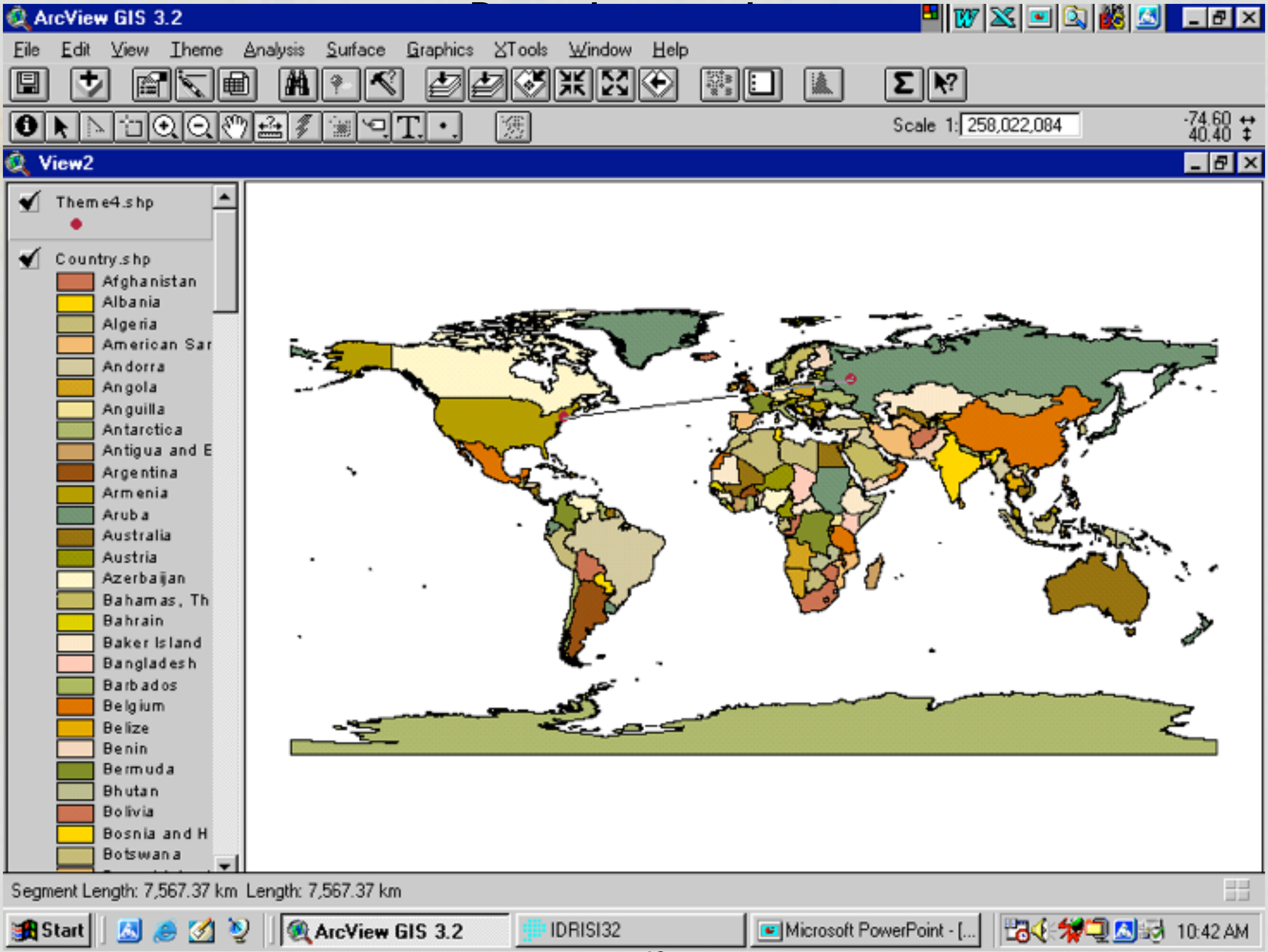
- The following mostly for vector GIS, but…
  - Gotta know a little SQL
    - Standard or Structured Query Language
    - Specific language for both data entry (build and create database) and data query
    - Operators =,>,<,>=, <=, <>
    - Some applications built in with user interface, other applications less structured
    - Generally watch syntax!
  - Gotta know a little Boolean logic (Generally true/false)
    - AND both conditions met for true
    - OR one condition met for true
    - NOT negates condition (so true to false, false to true)
    - XOR true only where each condition is exclusively true
  - Gotta know how your variable/data type is defined in database
    - Nominal, Ordinal, Ratio, Interval, Binary, Cyclical
    - Date, Character, Float/Decimal, Integer, Boolean, others

Query – More

- For spatial queries, we can also do other simple queries that used to require overlay analysis, which is even better in the object-oriented programs like ArcGIS
- Most of these searches must use some form of topology, logic, and advanced SQL to work
- Remember that I get the attributes with these
- Finally, have to know your dimensionality (0,1,2,3) for application, but most of these relate to the vector model
  - Equal – are the geometries the same?
  - Disjoint – do the geometries share a common point?
  - Intersects – do the geometries intersect?
  - Touches – do the geometries intersect at their boundaries?
  - Crosses – do the geometries overlap?
  - Within – is one geometry within another?
  - Contains – does one geometry completely contain another?
  - Overlaps – do the geometries overlap?
  - Relate – are there intersections between the interior, boundary, or exterior of the geometries?

Measurements and Directions

- Extracts measurements of distance, area, perimeter, direction, and shape given geometry, units, attributes, and behavior
- Connectivity, Flows, Proximity
- You've used these a lot in your labs
- Also should mention buffering as a common analysis tool
- Gotta know your data model
  - Raster – Limited by resolution of the cell
  - Vector – Potential for much higher accuracy than raster
    - Network for directions
- Gotta know your georeferencing!!!
  - Spherical vs. planar
    - Nautical mile (includes curvature of earth) 1.151 miles vs. mile
  - Datum, Projection, Coordinate System?...Reference Units?
  - Grid North, Magnetic North, or True North?
  - Gotta be able to do conversions for units
  - These are a really big deal, and where problems can occur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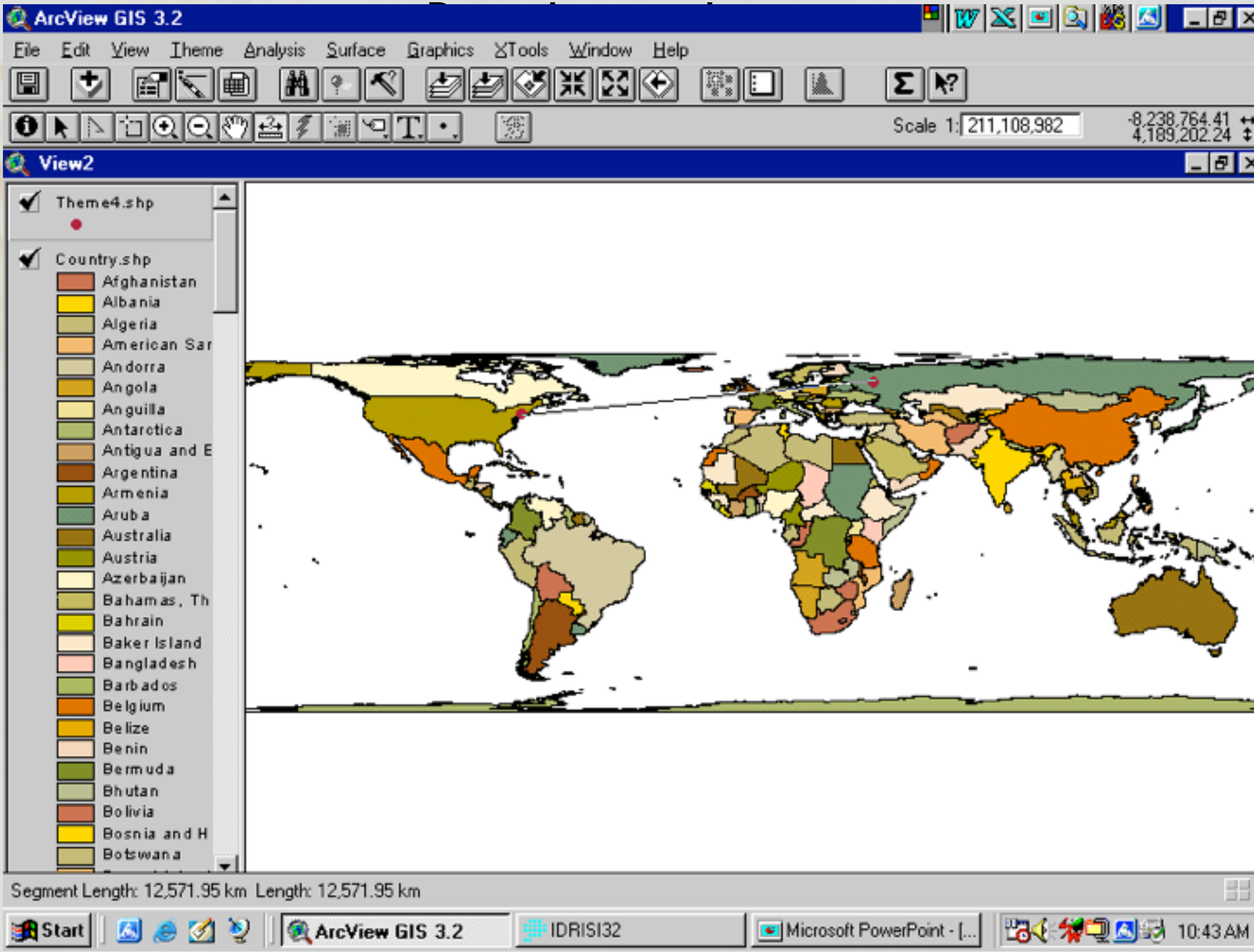
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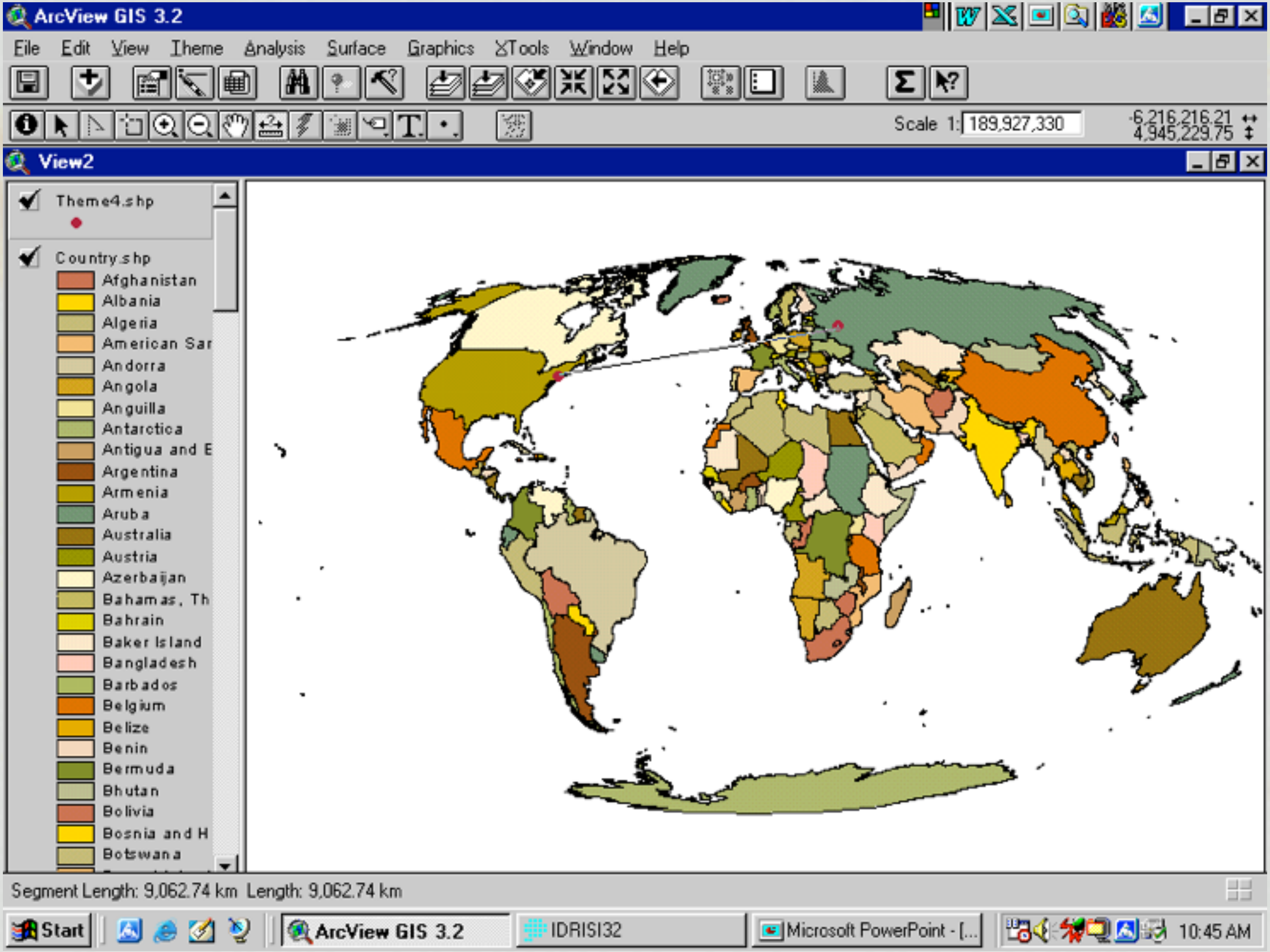
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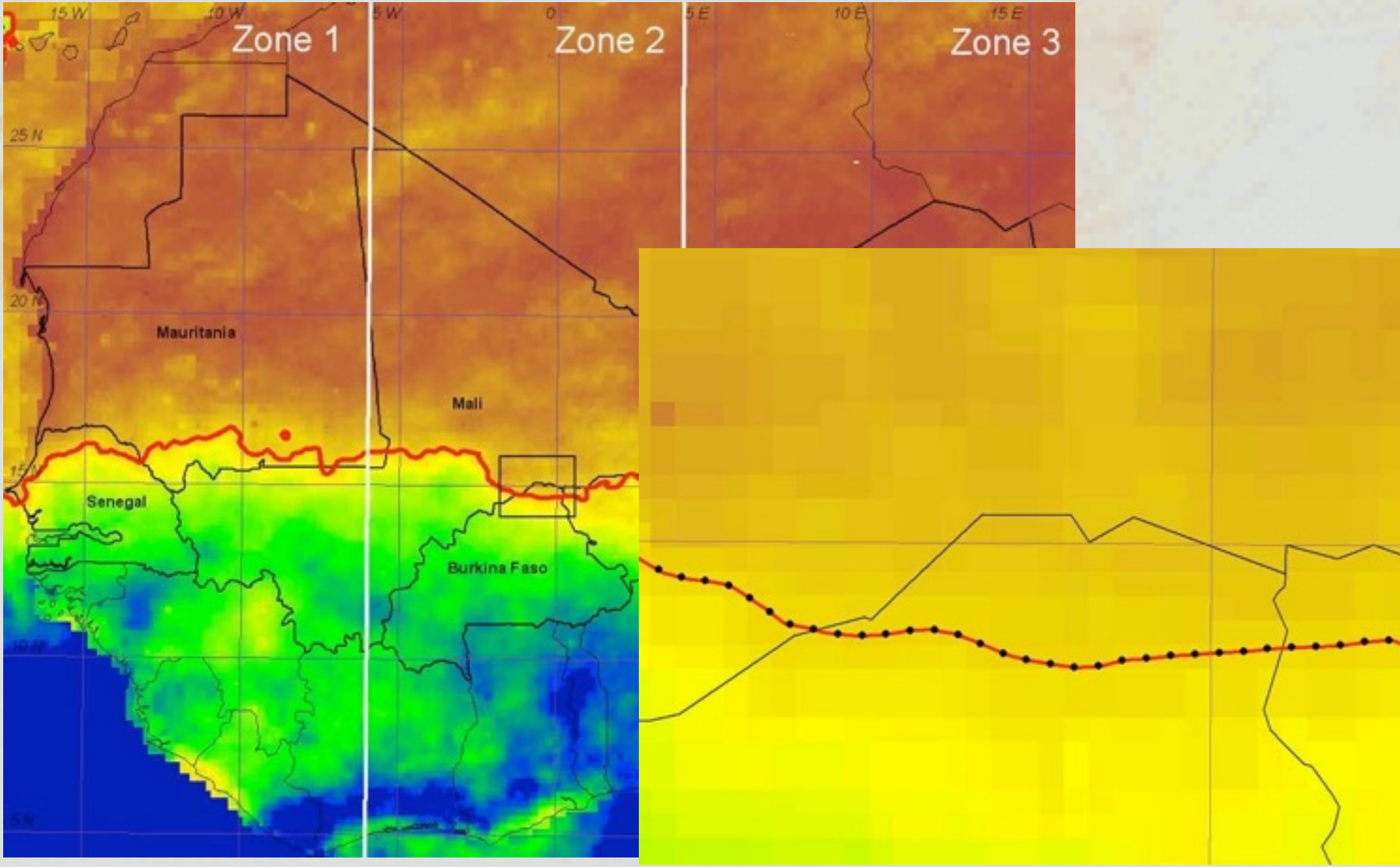
Rumsliga analyser

Descriptions

- Spatial and Statistical
- Capture nature of distributions and patterns
- May be across space, time or themes
- Can query and provide summary of results from attributes
- May or may not manipulate original data
- Statistics extracted from data set
  - All the stuff you already know from statistics
  - Histograms, scatter plots, etc…
  - Summarize
  - Time series
  - Moran's I
- Spatial
  - Lot's of them…continuing in development with new concepts
    - Generally related to spatial autocorrelation and heterogeneity
  - But also some basics, like the centroid…our spatial notion for centrality – finds the center point in polygons
  - Spatial Interpolation IDW, Kriging, Density Estimation, Dispersion

Rumsliga analyser



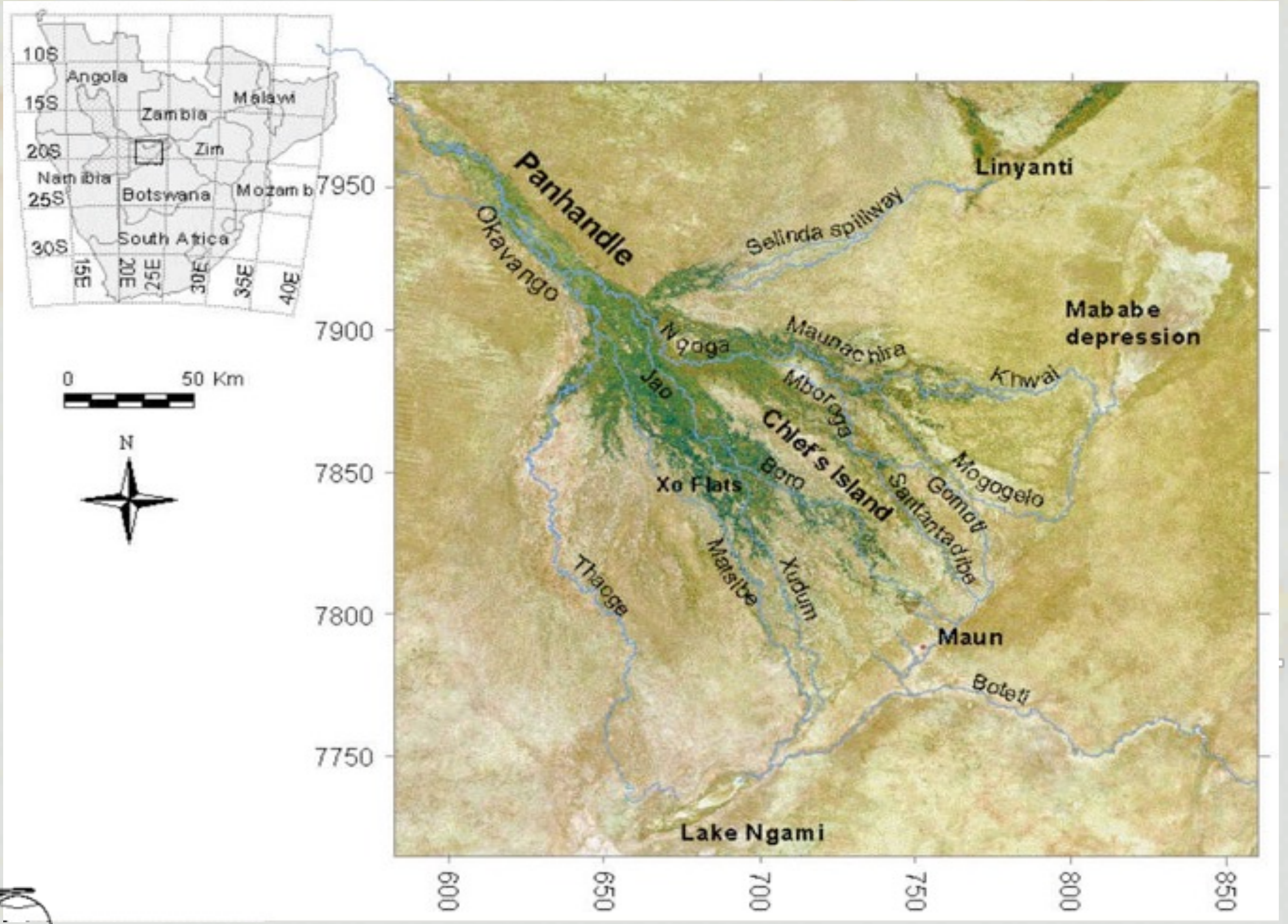
Exempel: Hur beskriva Nord-Syd position hos en vektor- Sahel

Geometriska vektoroperationer

Beräkning av längdaxel och riktning

Exempel Okavango

Exempel: Öar i Okavango deltat



Exempel: Öar i Okavango deltat

Primary islands built from accumulation of clastic sediments

Island types

Inverted channel island

Exempel: Öar i Okavango deltat

Primary islands built from accumulation of clastic sediments

Island types

Scroll bar island

Exempel: Öar i Okavango deltat

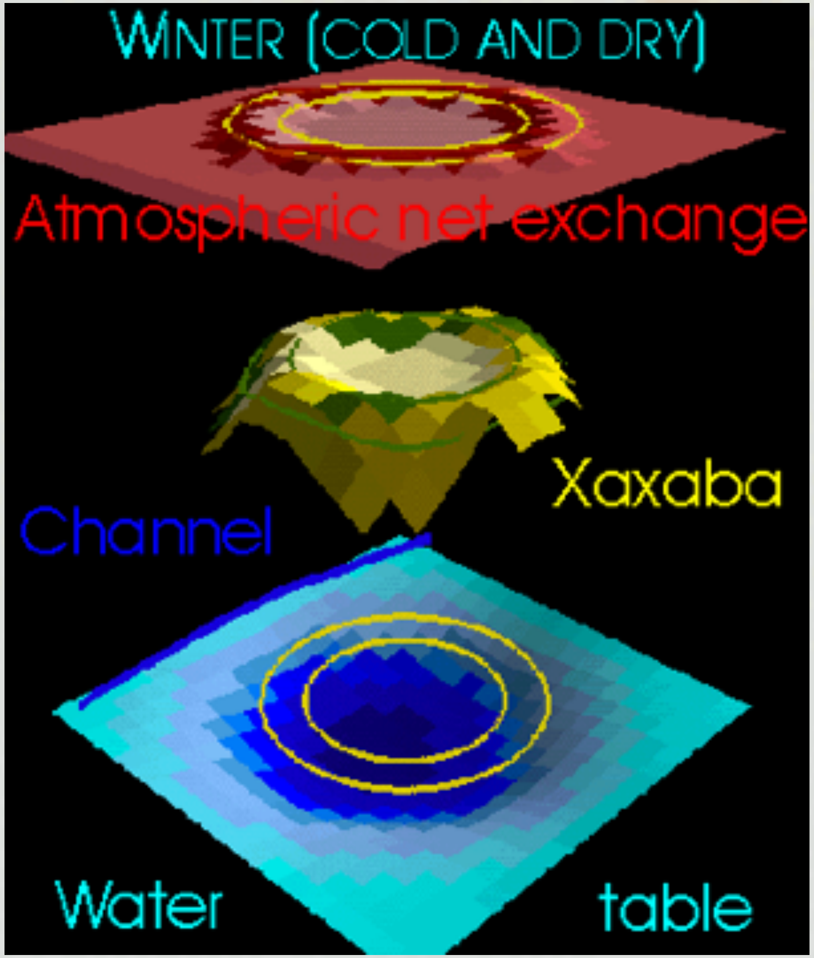
Primary islands built from accumulation of clastic sediments

Island types

Anthill island

Exempel: Öar i Okavango deltat

Evapotranspiration, salinity balance and island secondary growth



Exempel: Öar i Okavango deltat

Secondary islands grown from precipitation of chemical sediments

Island types

Riparian forest island

Exempel: Öar i Okavango deltat

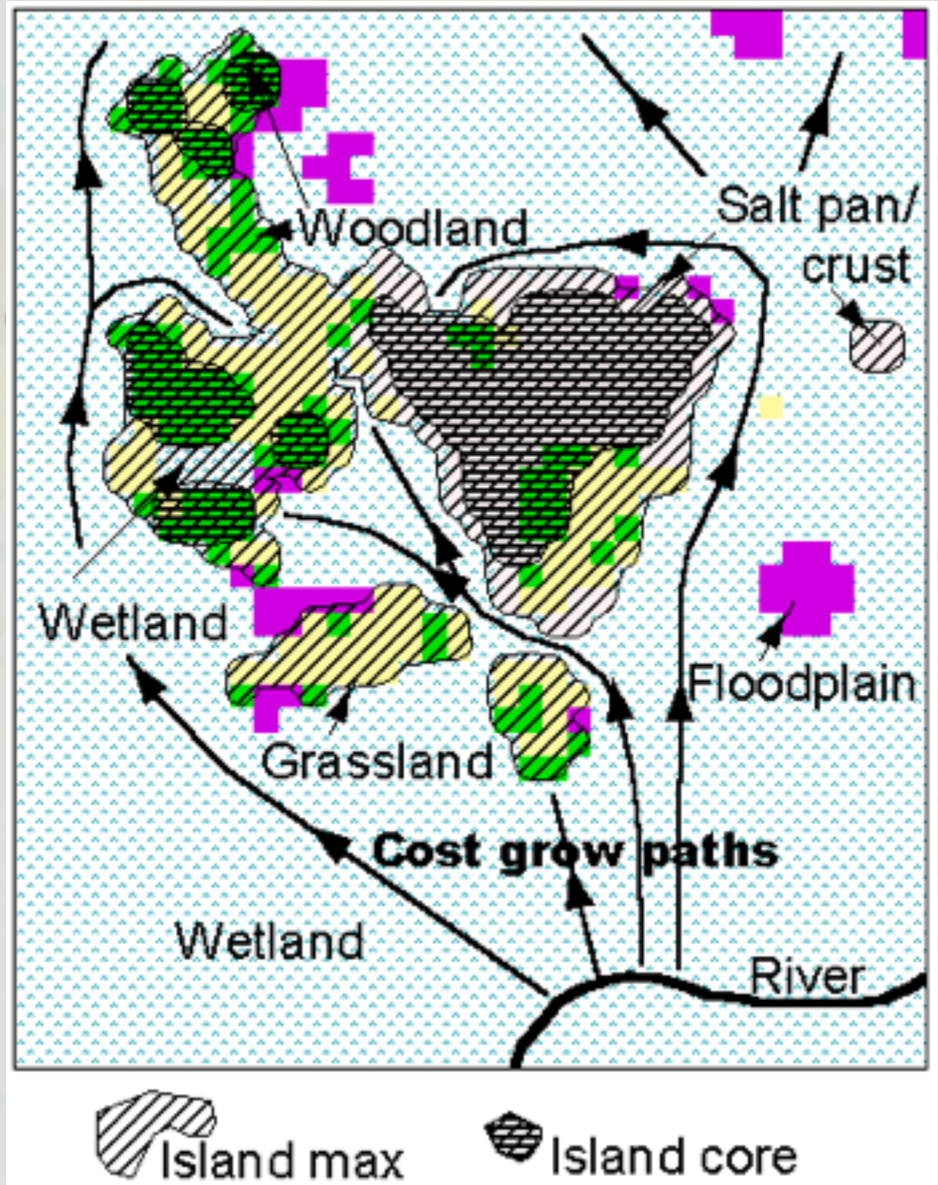
Secondary islands grown from precipitation of chemical sediments

Island types

Salt island

Exempel: Öar i Okavango deltat

Exempel på Transformation raster till vektor



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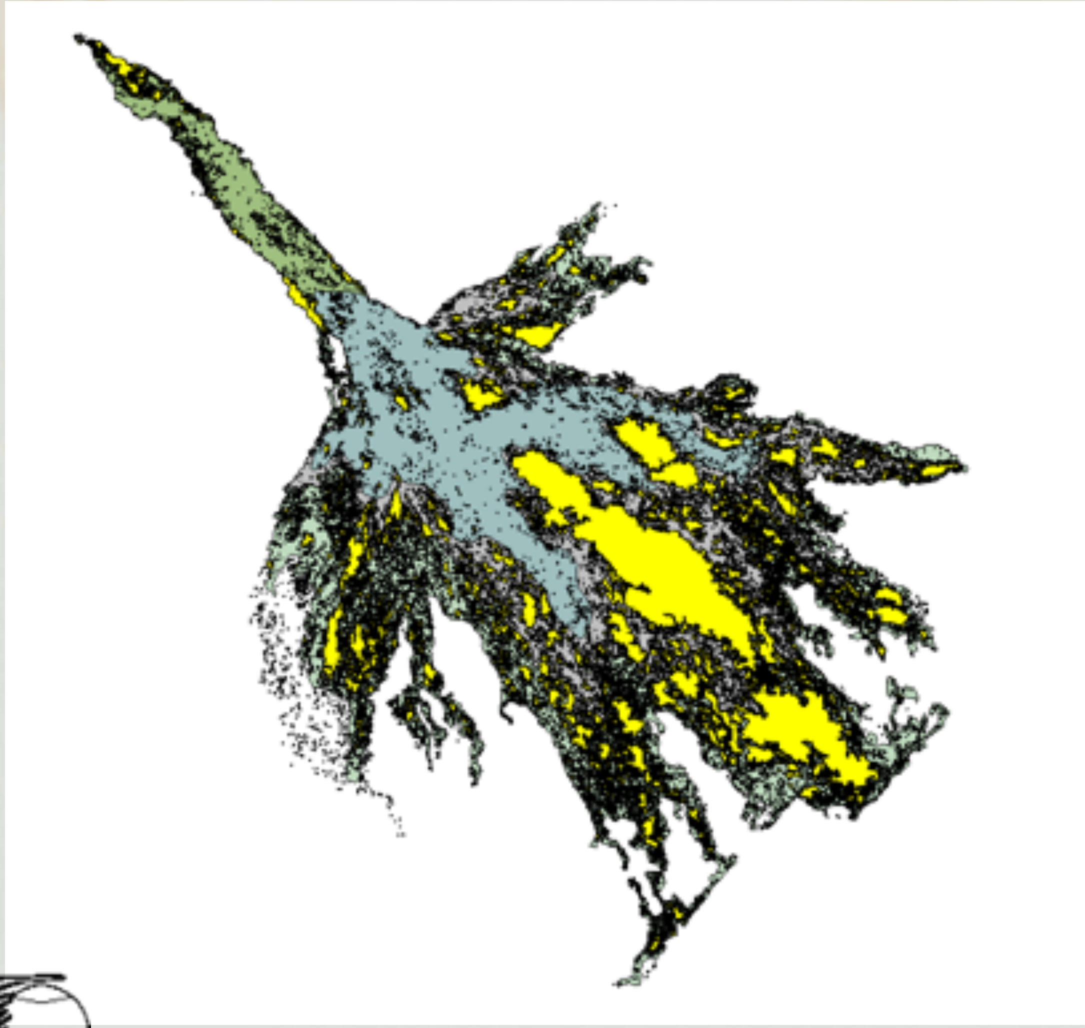
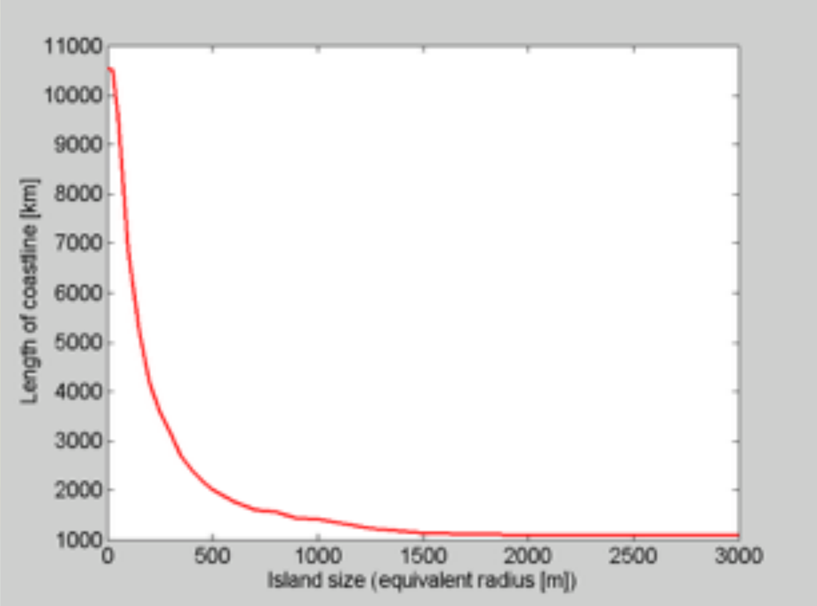
Exempel: Öar i Okavango deltat

Salt Balance: Coastline from Remote Sensing



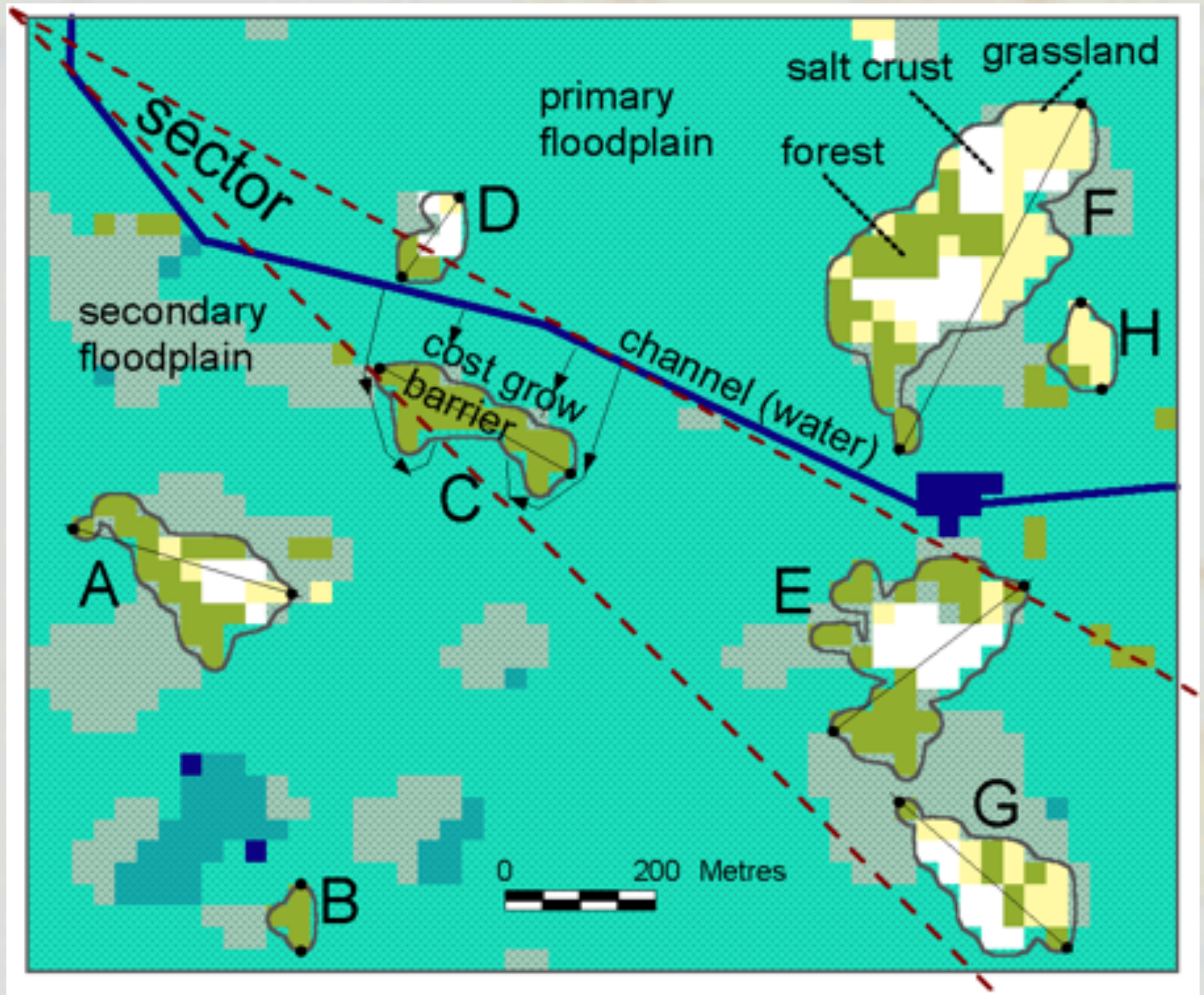


Exempel på Hypotesprövning

Exempel: Öar i Okavango deltat

Extraktion av längdaxel och beräkning av riktning

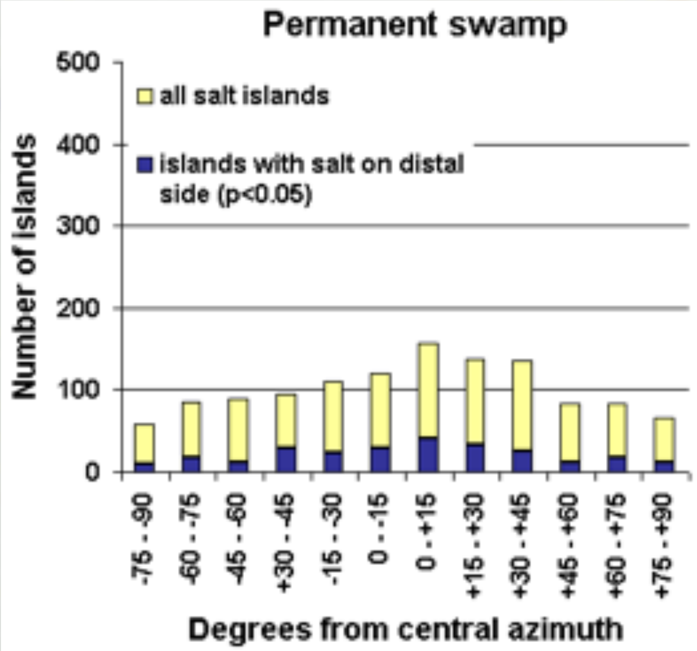
Exempel på mätning

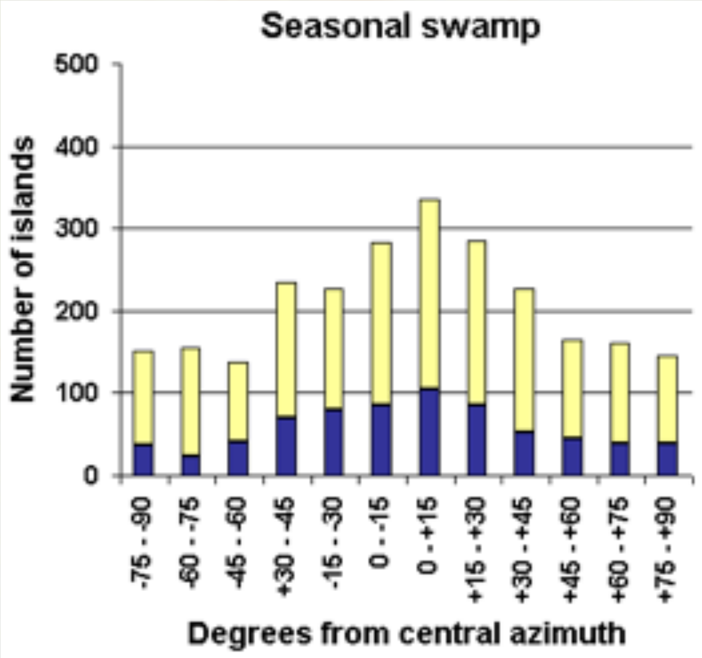


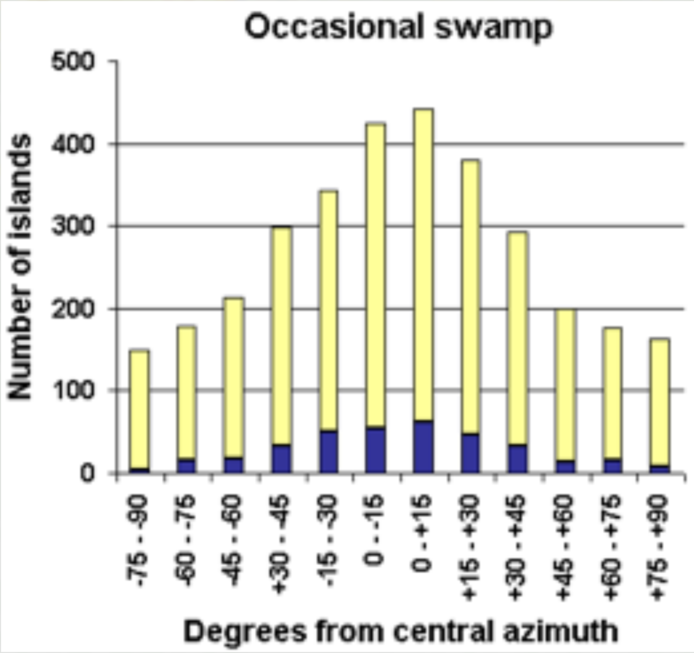
	A	B	C	D	E	F	G	H
Roundness	0.49	0.91	0.51	0.48	0.36	0.47	0.58	0.92
Regional salt position	distal*	na	na	proximal	distal	equal	proximal	na
Channel salt position	front	na	na	back	back	back	back*	na

Exempel: Öar i Okavango deltat

Öarnas längdriktning i relation till Deltats riktning



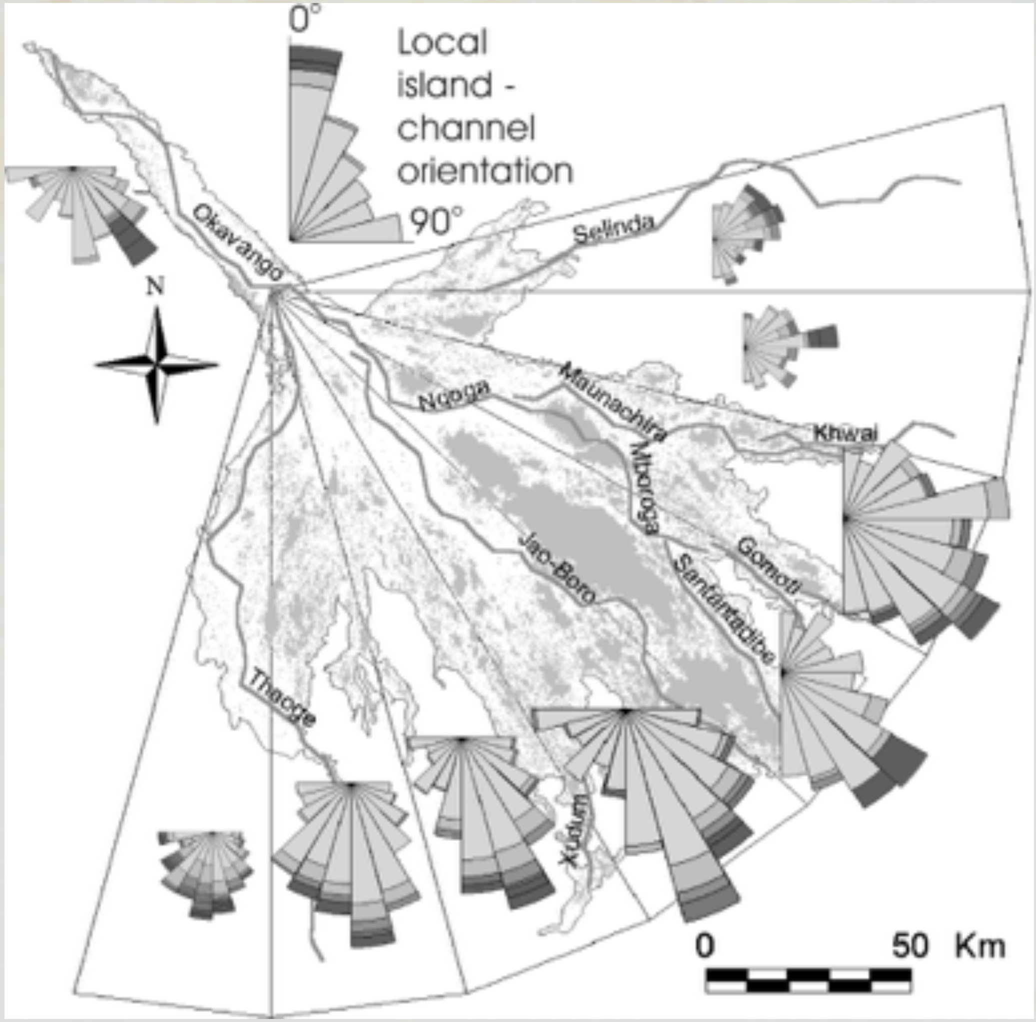




Exempel på deskriptiv metod

Exempel: Öar i Okavango deltat

Öarnas betydelse för uppdelningen av vattenföring och indelning i bassänger



Exempel på deskriptiv metod

- Geometriska vektoranalyser

Geometriska vektoroperationer

Beräkning av avstånd

Euklidiskt avstånd

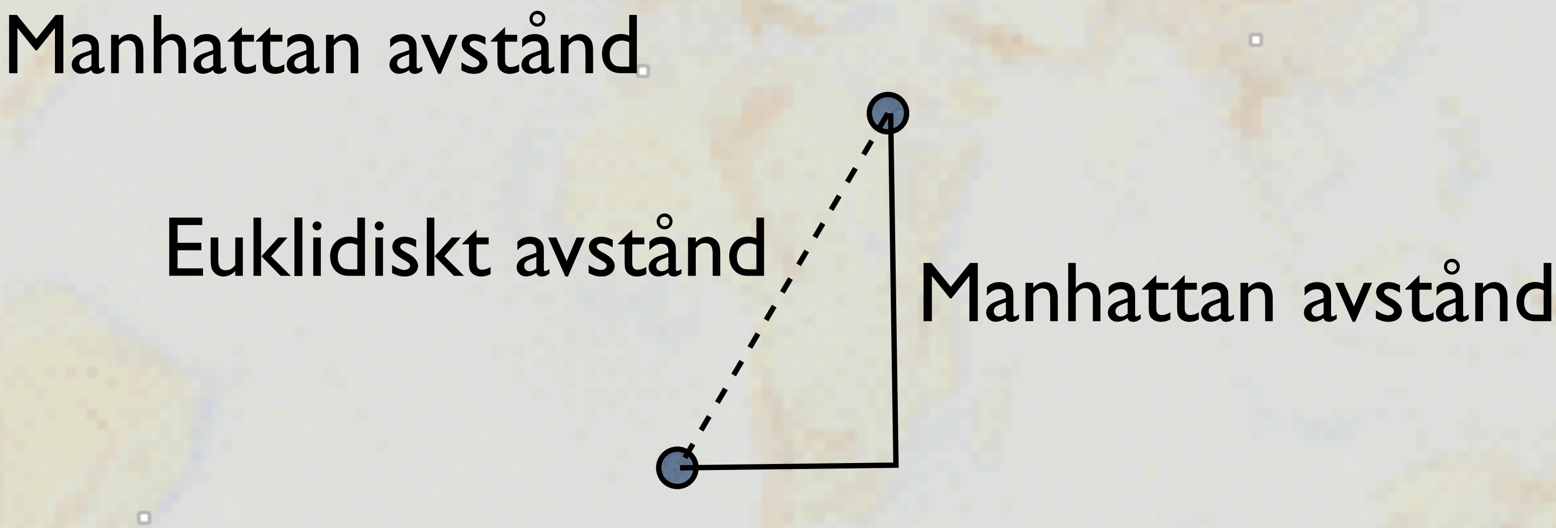
$$d(1,2) = \sqrt{(x_1-x_2)^2 + (y_1-y_2)^2}$$

där

$d(1,2)$ är avståndet mellan puntkerna 1 och 2
punkt 1 har koordinaterna (x_1,y_1) och,
punkt 2 har koordinaterna (x_2,y_2).

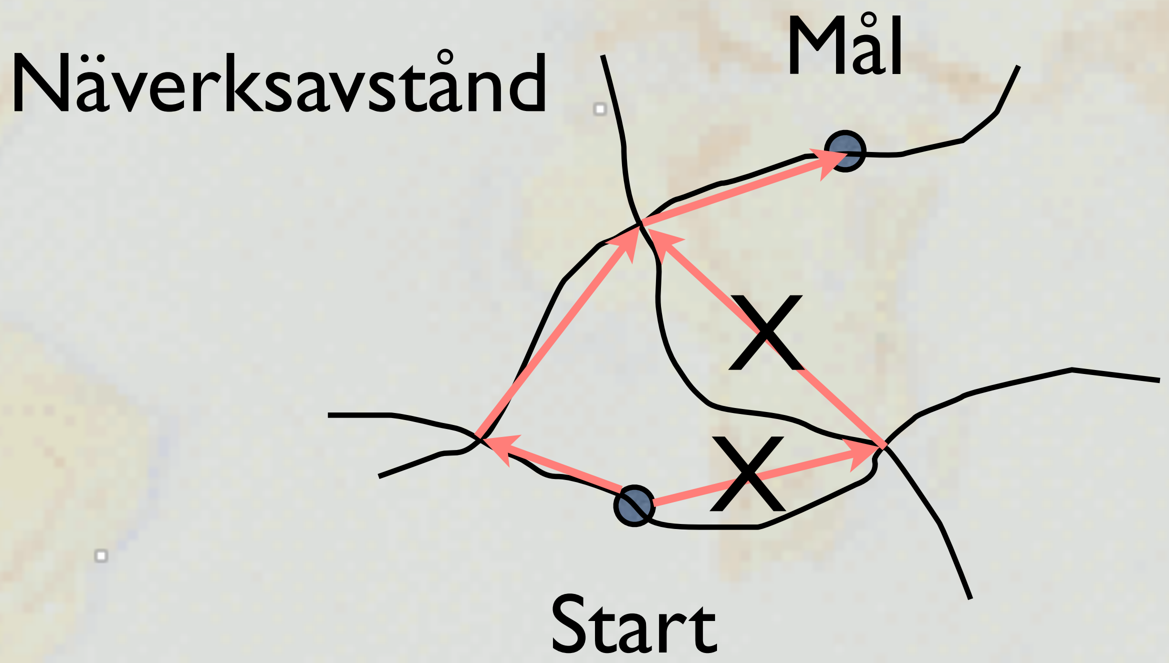
Geometriska vektoroperationer

Beräkning av avstånd



Geometriska vektoroperationer

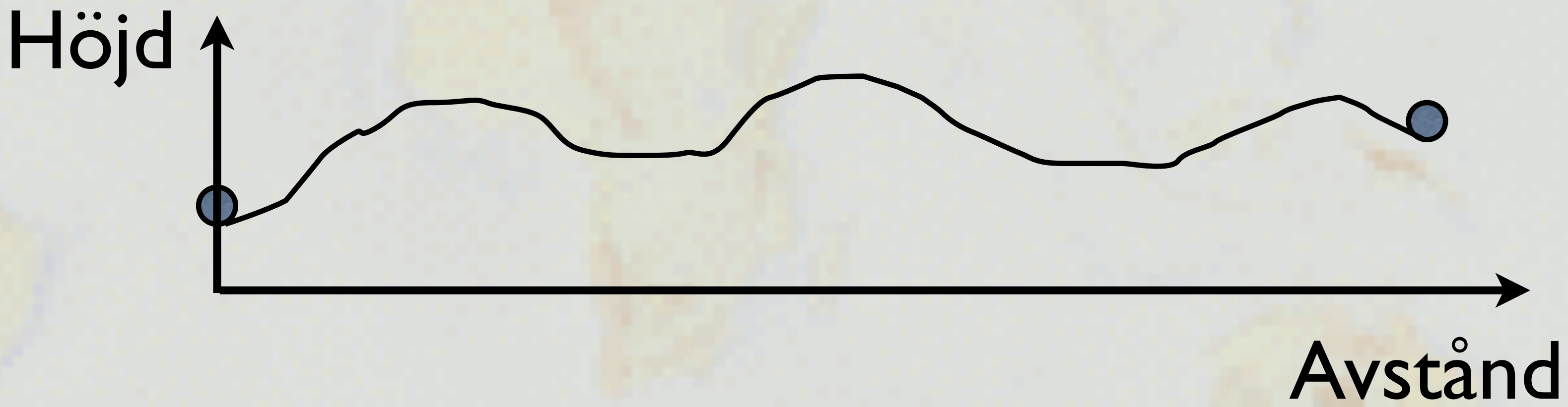
Beräkning av avstånd



Geometriska vektoroperationer

Beräkning av avstånd

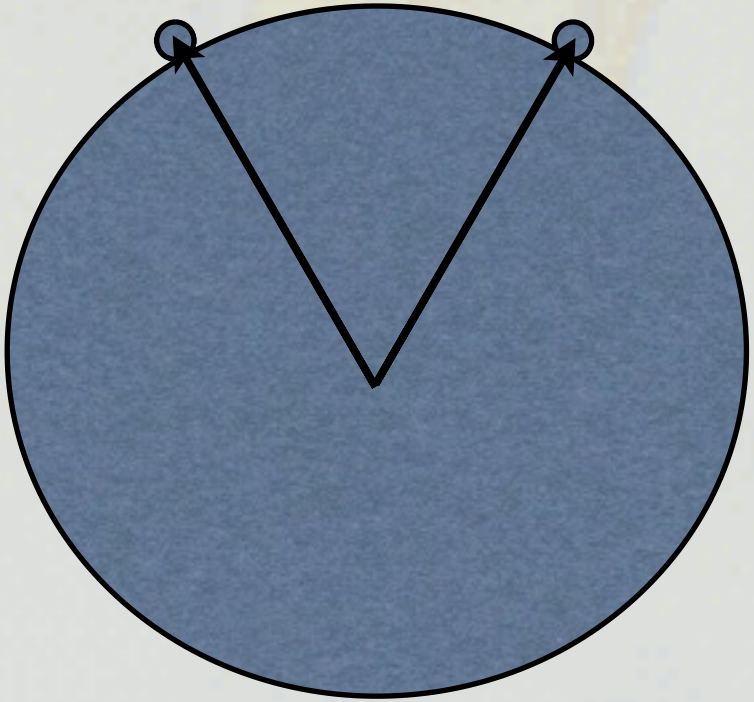
Topografiskt avstånd (över 3D yta)



Geometriska vektoroperationer

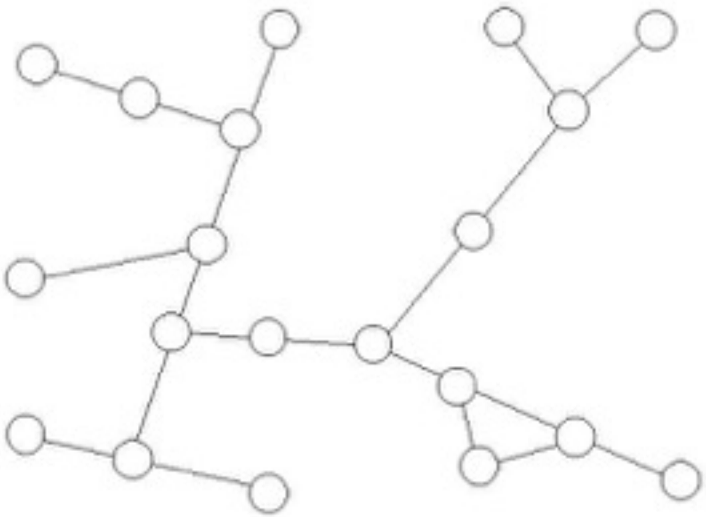
Beräkning av avstånd

Sfärsikt avstånd (med hänsyn till jordyans rundning)



Nätverk

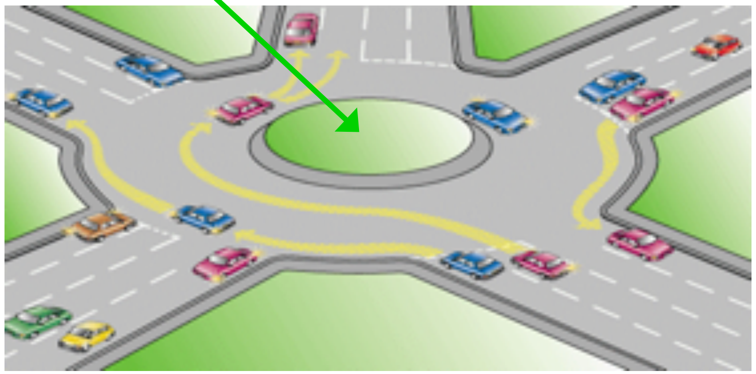
Network algorithms



Network data structure:

- vertices/nodes and edges/links
- used for road databases

- links meet at junctions (nodes) but not at crossings



Attributes of links

flow direction

length of link

speed limit

different cost in different directions

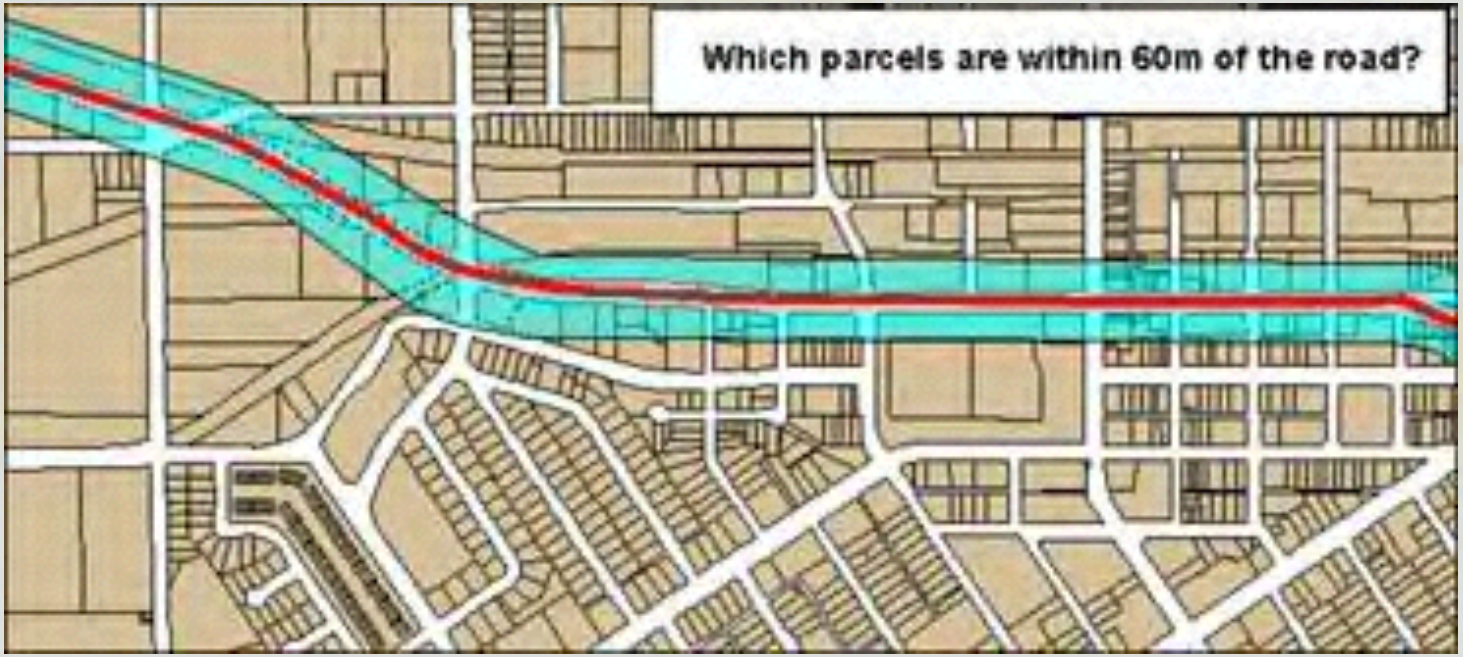
Connectivity Functions

- Used to accumulate values over an area being navigated
- Parameters to define:
  - specification of way spatial elements are connected
  - rules that specify allowed movement along interconnections
  - a unit of measurement

Connectivity Functions (cont).

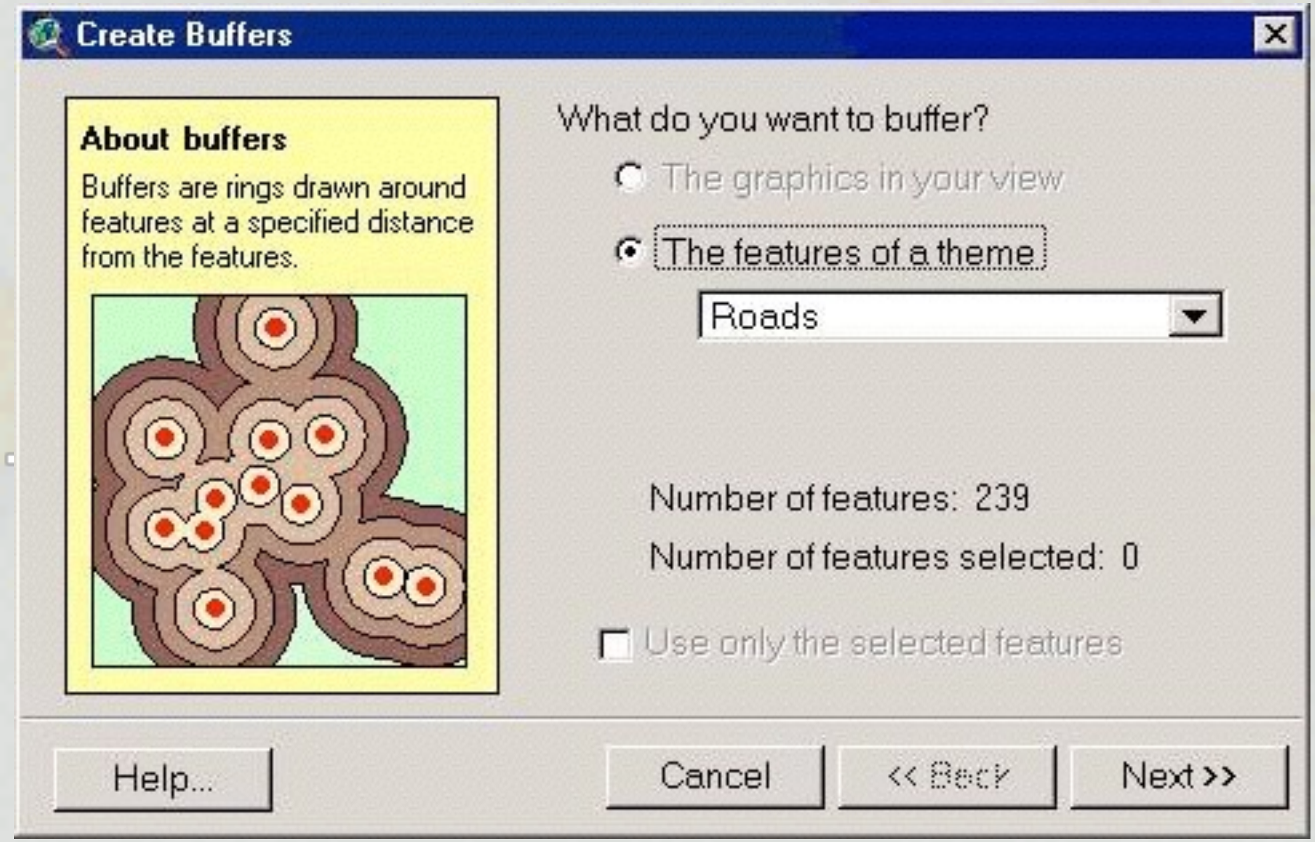
- Proximity Operation
  - measure of the distance between features
  - not restricted to distance; can be noise, time, pollution, etc.
- Parameters to define:
  - target location
  - unit of measure
  - function to calculate proximity (distance/time/noise)
  - area to be analyzed

Example: Connectivity (Vector)



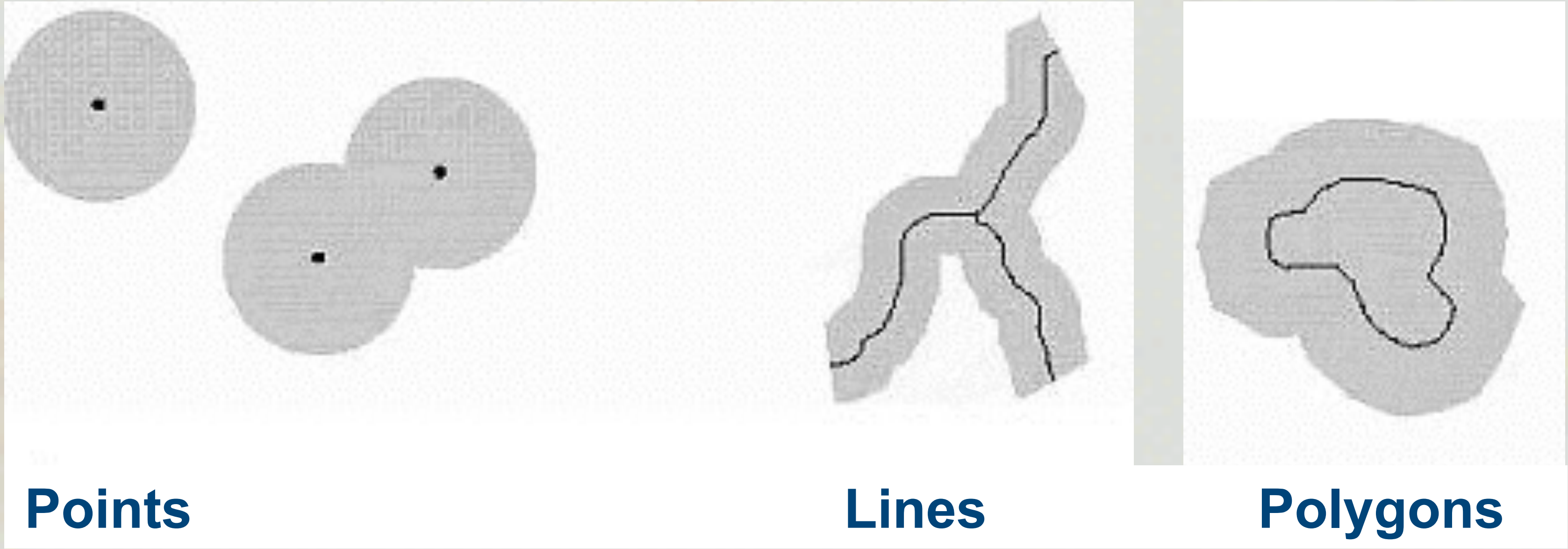
Proximity Operation: Road Buffer

Example: Connectivity (Vector)



Proximity Operation: Buffer Generation

Example: Connectivity (Vector)



Proximity Operation: Buffer Types

Example: Connectivity (Vector)
Proximity Operation - Buffers & Setbacks

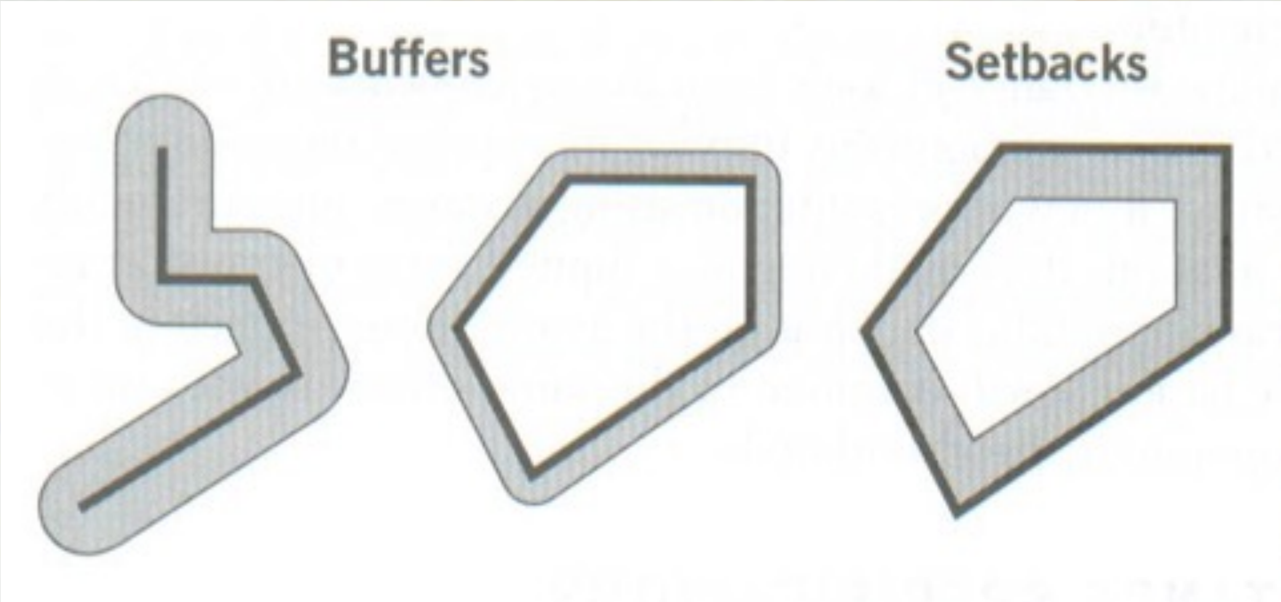


Diagram of simple buffers and a setback.
NOTE: buffers go outward from lines or areas; setbacks run inside of areas (not lines).

Connectivity Functions (cont).

- Contiguity Operation
  - spatial units are connected - defines “unbroken area”
- Contiguity measures:
  - size of neighboring area(s)
  - shortest/longest straight line distance across adjacent area(s)
  - specific shape of neighboring area(s)

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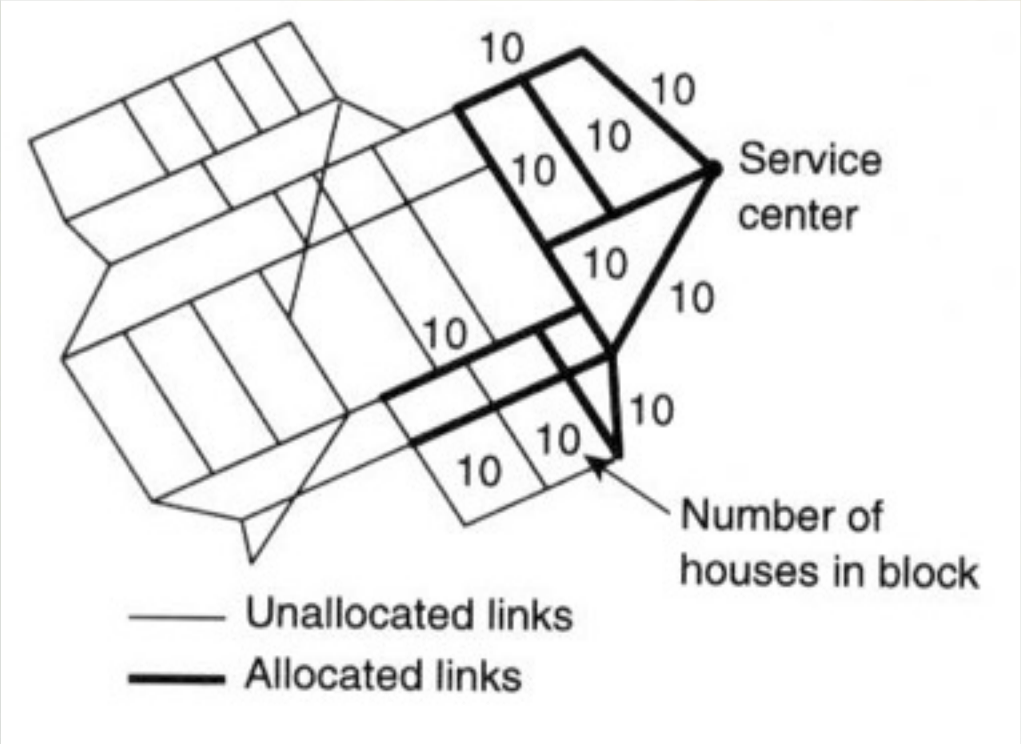
Connectivity Functions (cont).

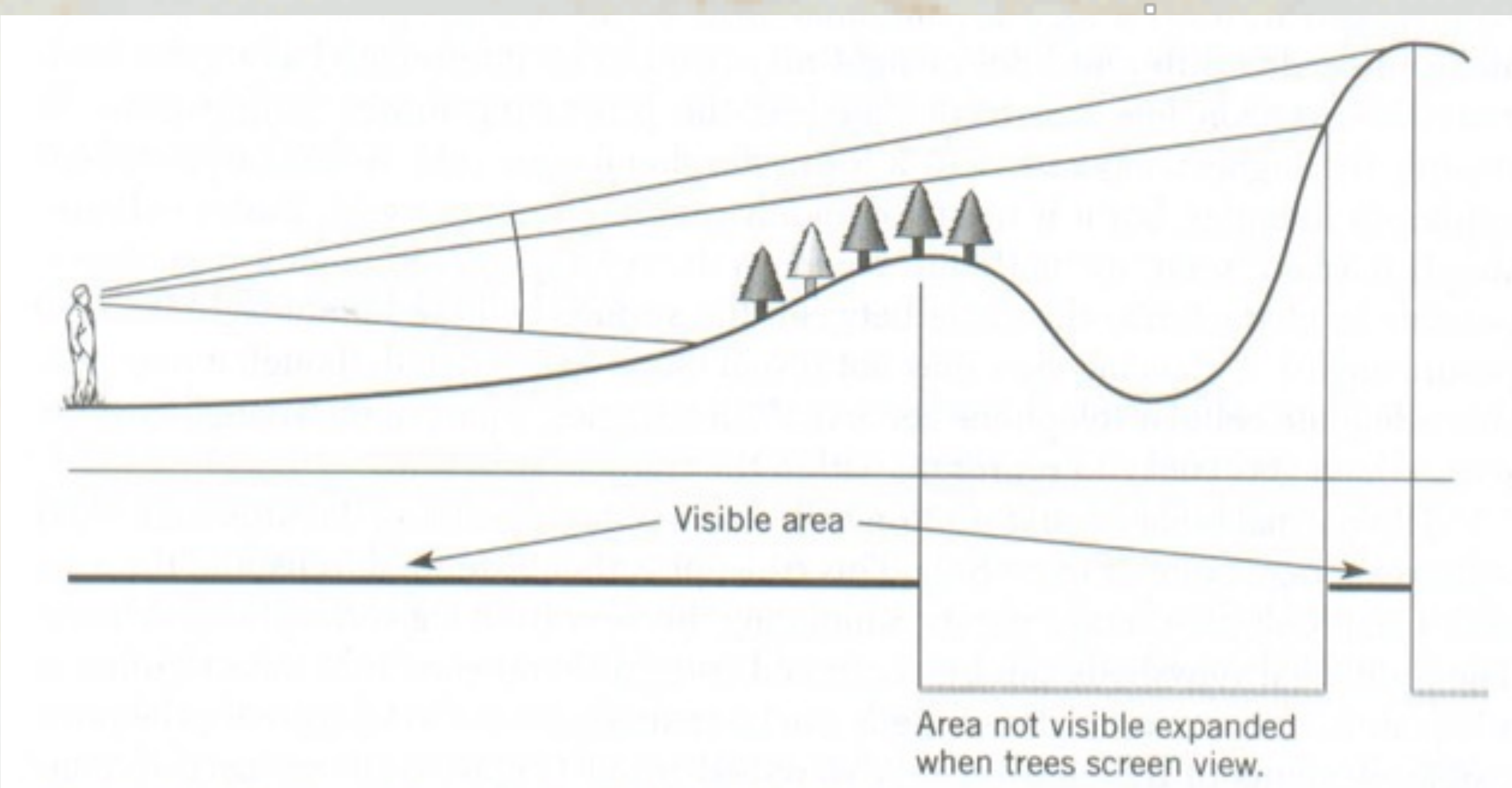
- Network Operations
  - set of interconnected lines that represent a set of features through which resources flow
- Common network functions
  - shortest path problem (route optimization)
  - location-allocation modeling (resource allocation)
  - traveling salesperson problem (route optimization)
  - route tracing (prediction of network loading)

Example: Connectivity (Vector)



Network Function: Location-Allocation

Connectivity Function Example: Viewshed Analysis



Connectivity Functions (cont).

- Visibility Analysis Operations
  - identification of areas of terrain that can be seen from a particular point on the surface
- Viewshed Operation
  - uses digital elevation model data (DEMs) or.....
  - digital terrain model data (DTMs) or......
  - triangulated irregular network data (TINs)?

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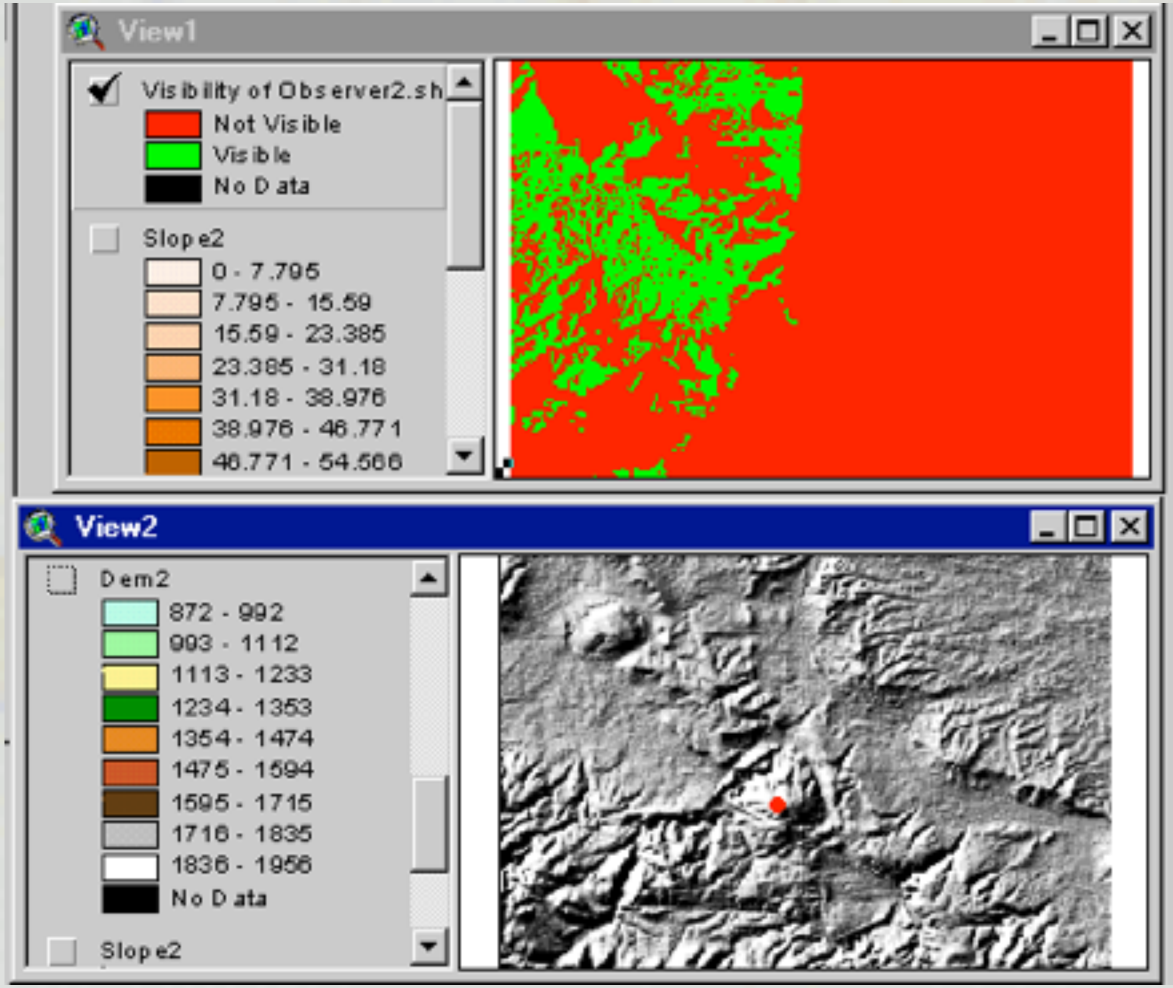
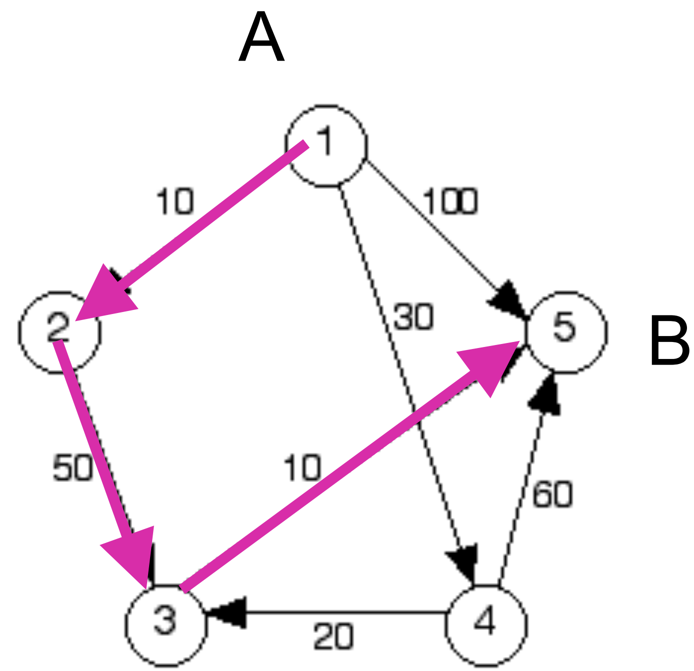
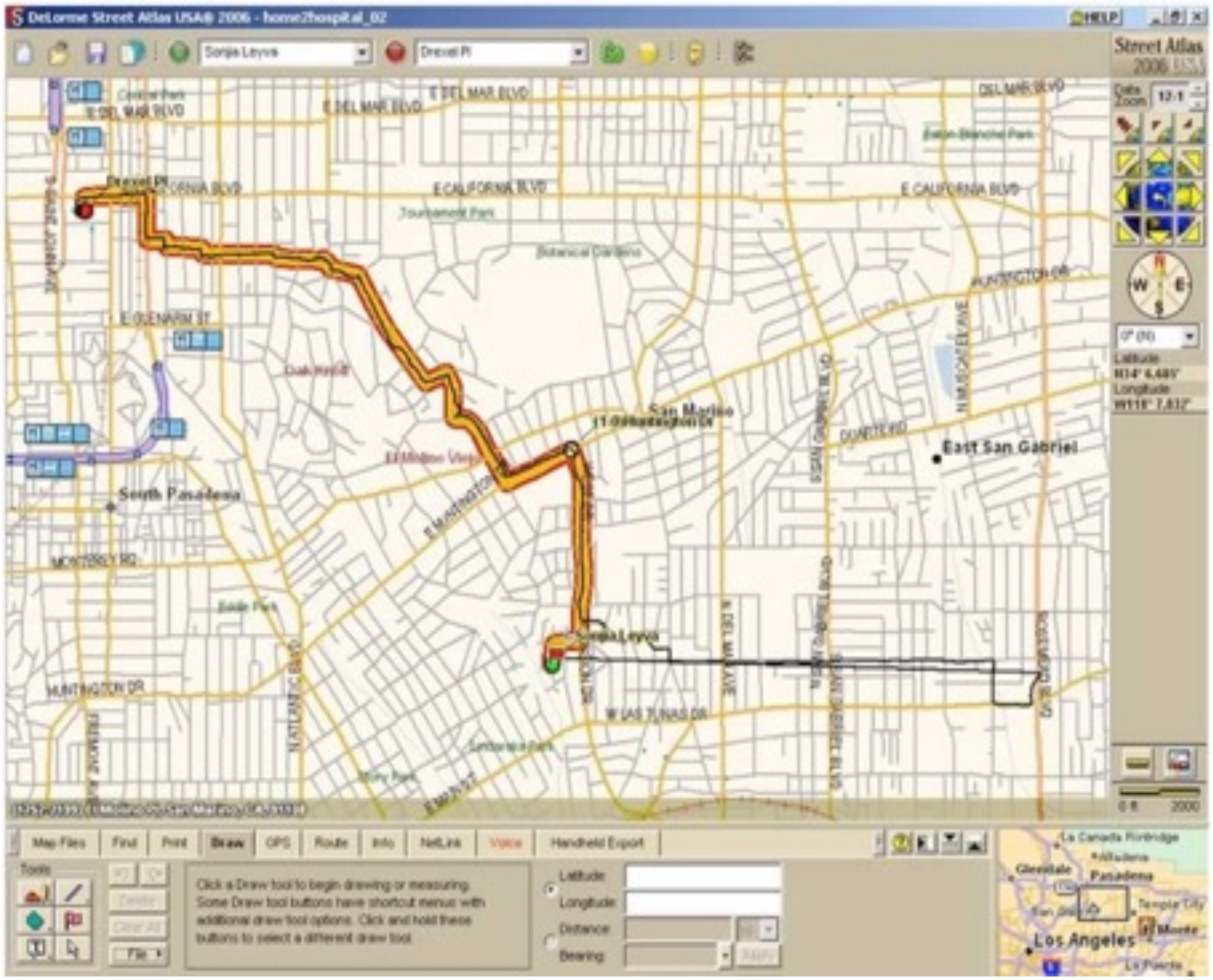
Nätverksanalyser



Network algorithms

Dijkstras algorithm – find the **shortest route** from point A to point B.





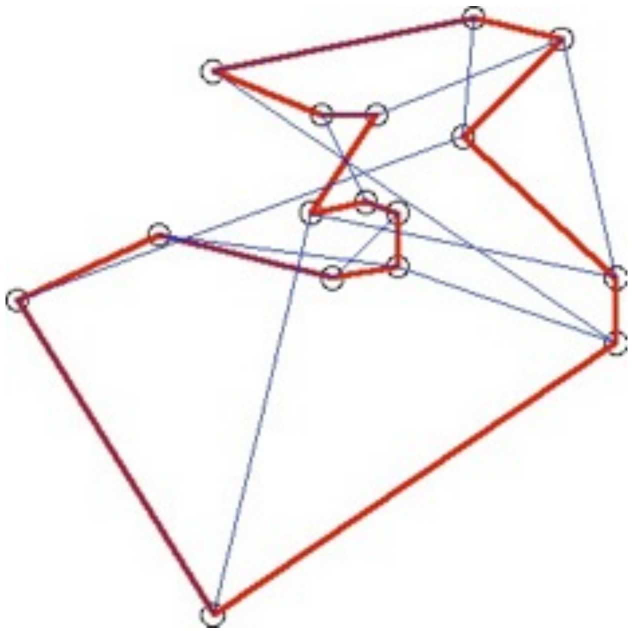
Application:

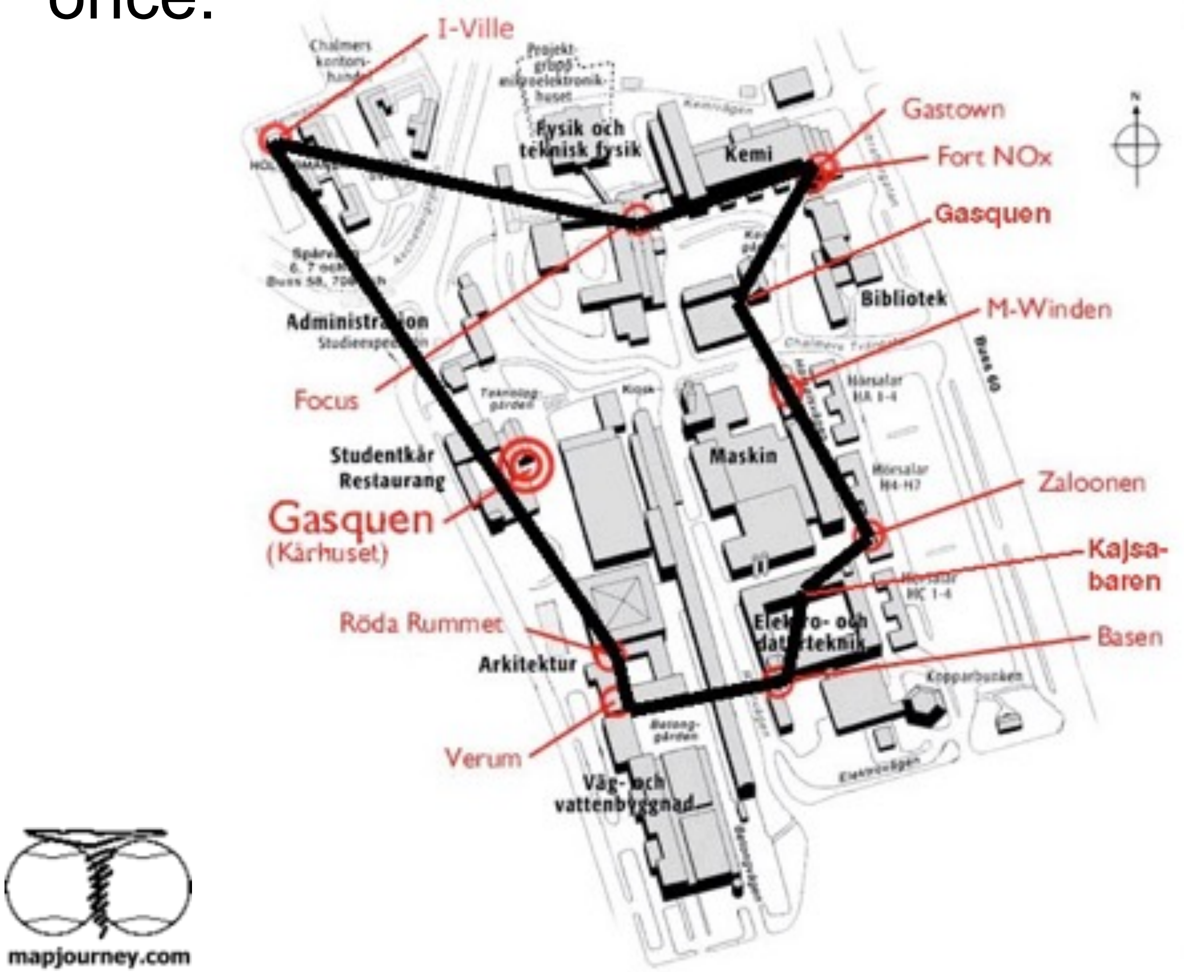
- ambulance route from hospital to the accident

-The fastest route is not always the shortest route – edge weights: travel time/link length

Network algorithms

Travelling salesman problem – find the shortest route through all the nodes of the network so that each node is visited exactly once.

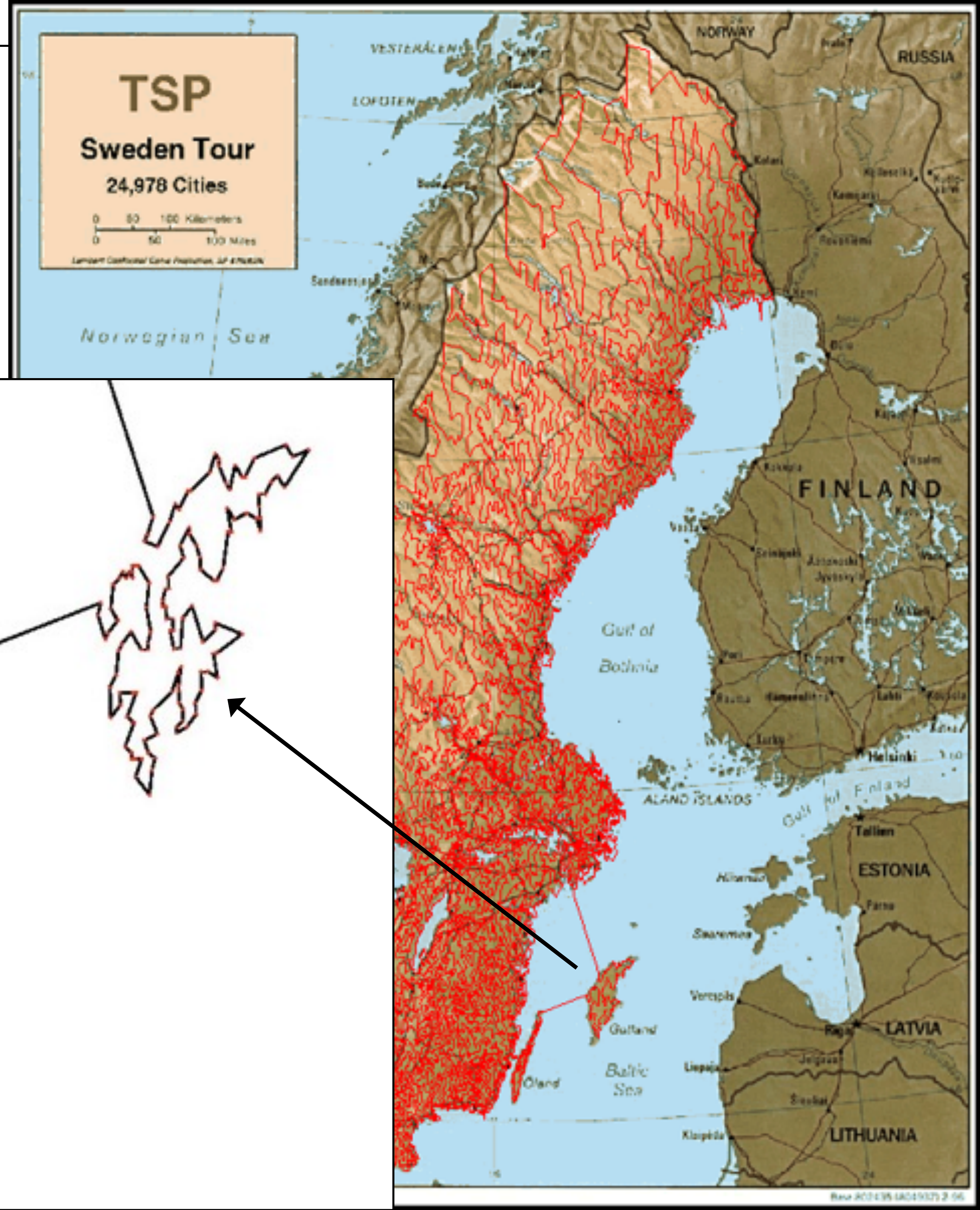


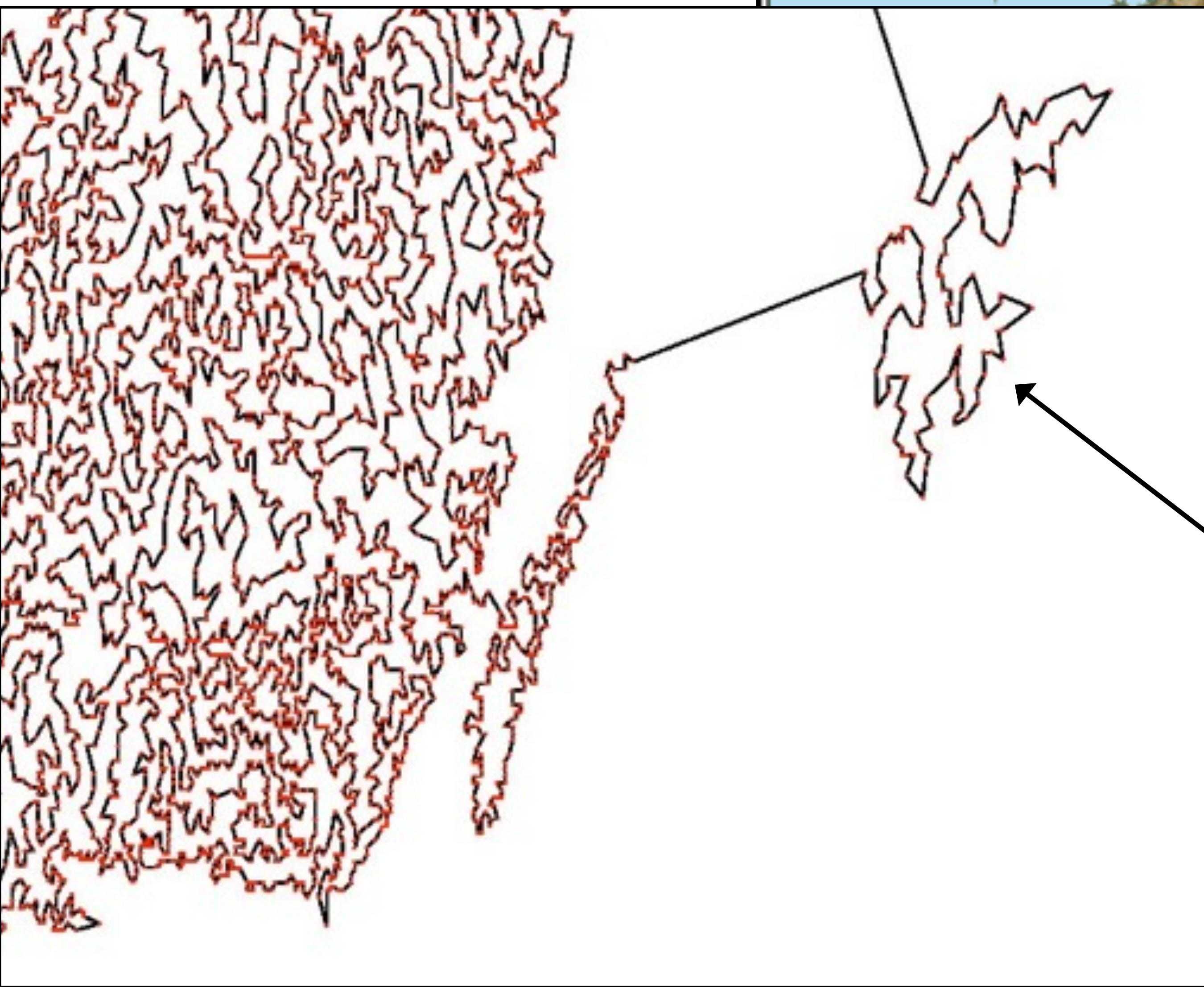


Applications:
- mail delivery
- planning a new bus line with specified bus stops
- the drinking student problem (visit all pubs at Chalmers) 😁

Travelling through 24978 cities/towns/villages in Sweden:

http://www.tsp.gatech.edu/sweden/index.html





Nätverksanalys

Sammanflöden och bifurkationer

Exempel Okavango

Sammanfattning

- Lots of different ways to analyze data to meet your purpose and deliver your outputs
  - Exploration, Queries, Measurements and Directions, Descriptions, Derivative Mapping, Reclassing, Manipulation, Overlay, Optimization, Simulation/Modeling
- Sometimes several ways to address the same problem
  - Problem solving, trouble shooting skills!!!
- You need to know GIS basics
  - GIS Process
  - Georeferencing
  - Data Types (how stored in database)
  - Data Models (raster vs. vector)
  - Data you have acquired
- Next Step?
  - Documentation – Metadata and Legal issues next

- “Data mining”

Geographic data mining

Data mining

Identifying or discovering useful and as yet undiscovered knowledge from the large real-world databases.

Knowledge → pattern → description of a subset of data points

Knowledge → model → statistical description of the whole dataset

Knowledge → relationship → dependency between attributes over a subset of the data

mapjourney.com

Dataanalys, Thomas Gumbricht, 2007

Types of data mining

Task

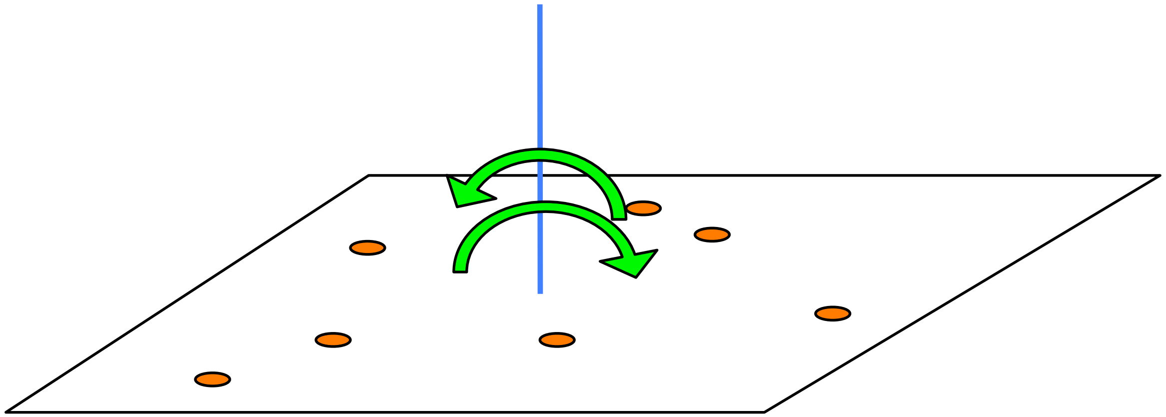
- Predictive DM
  - Goal: build a model to predict a value of one attribute from other attributes
  - classification, **regression**
- Exploratory DM
  - Goal: explore the data and identify the structure beneath
  - **summaries, clustering, visual DM**
- Reductive DM
  - Goal: data reduction – aggregate information in large datasets into smaller manageable subsets
  - principal component analysis

Descriptive summaries

Attempt to **summarise** useful properties of datasets in one or two statistics.

Find one or two **numbers** that describe the dataset.

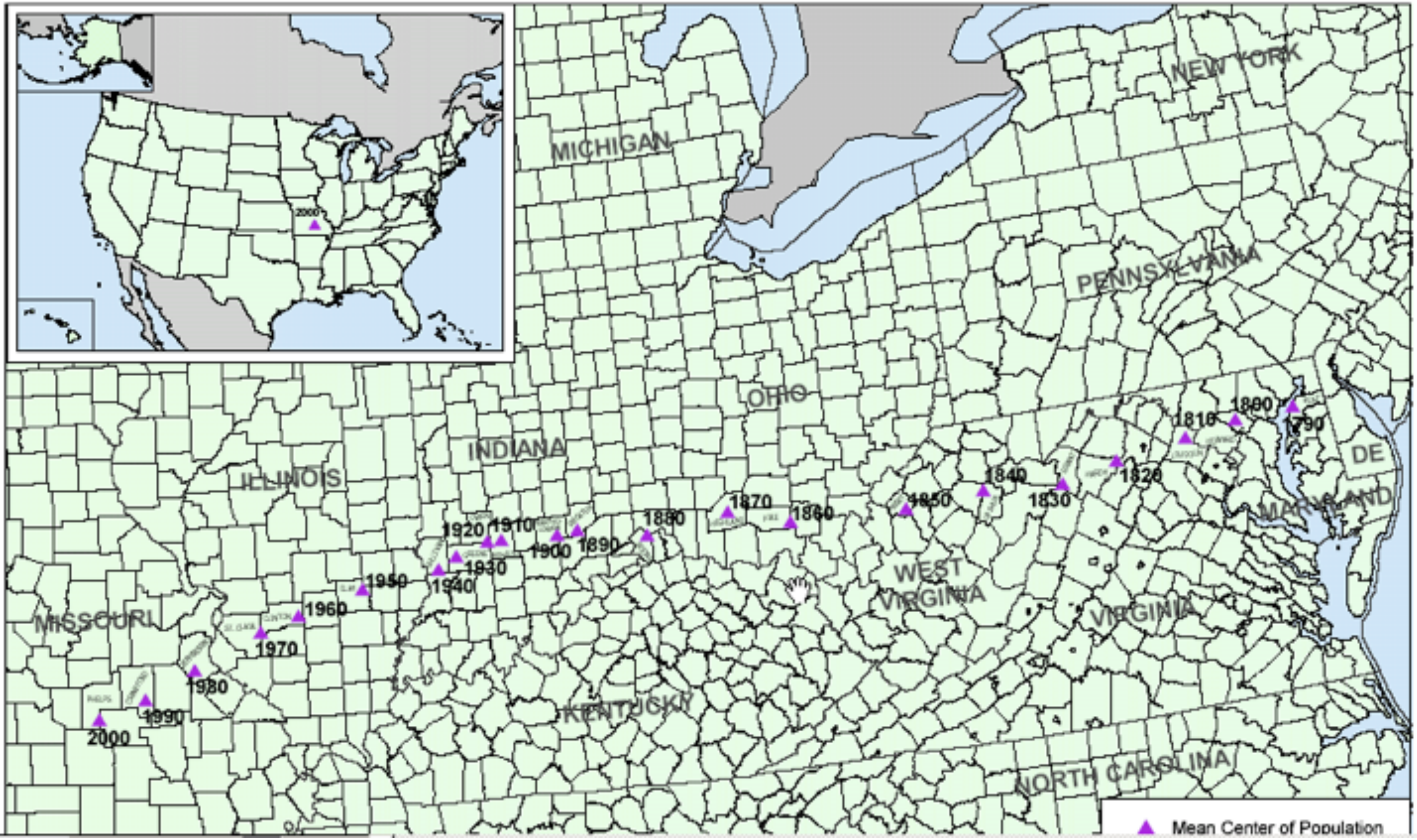
The **mean** or average is widely used to summarise data:
- the spatial equivalent = the **centre** of the data
- there are several ways of defining centres
- one example: **a centroid** = the weighted average of coordinates



The centroid = the balance point of the dataset

Dataanalys, Thomas Gumbricht, 2007

Mean Center of Population for the United States: 1790 to 2000



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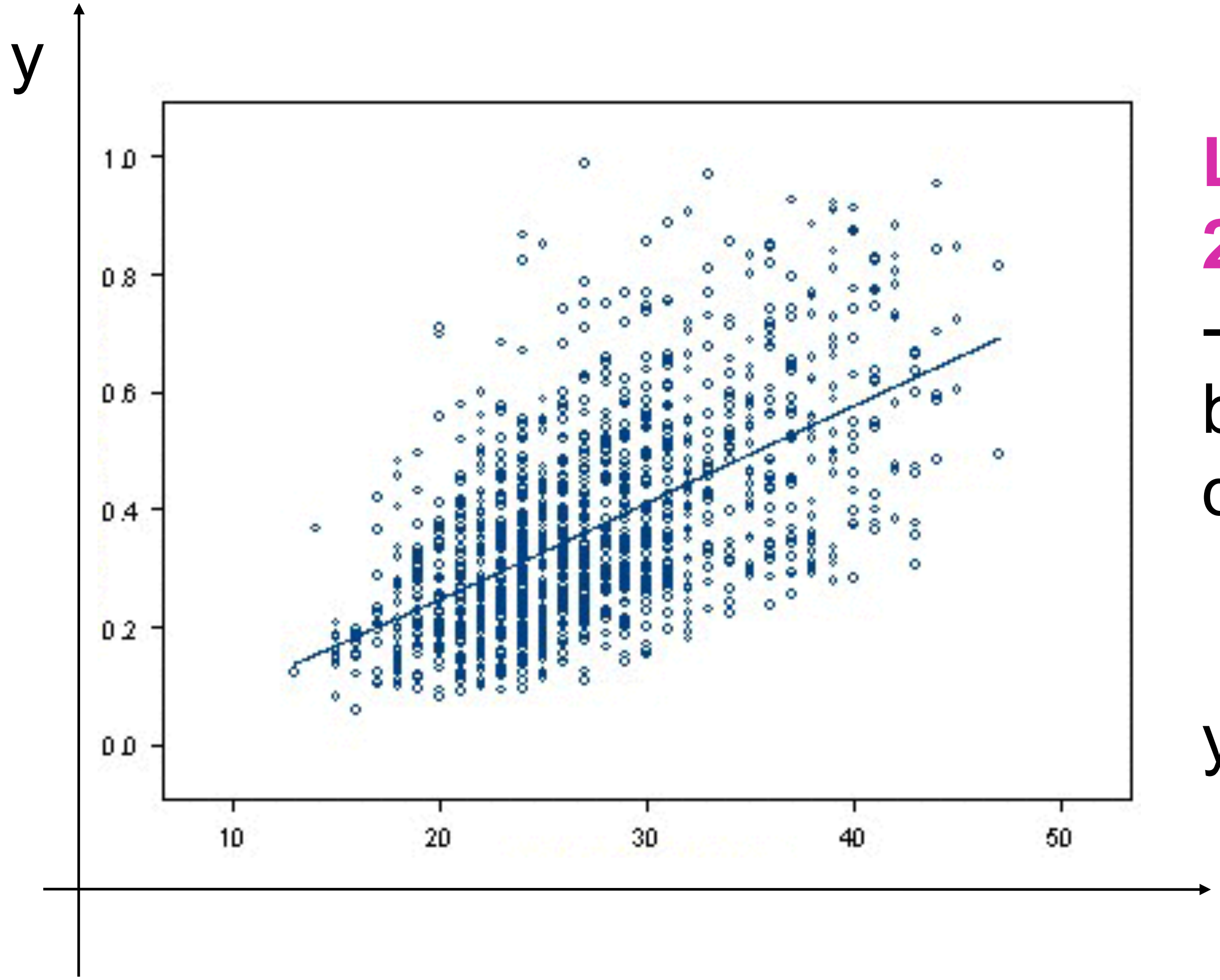
Regression analysis

Find **a line** that describes how one parameter depends on a large number of parameters:
- the parameters form a n-dimensional space
- least square methods are used to position the line in such a way that the shortest distance from the line to each point is minimised

floor space
age
standard of repair
radon level
distance to school
distance to park
etc.

Regression

Prediction of property value



Linear regression in 2 dimensions:

- find a linear line that best describes the point dataset

$$y = ax + b$$

Linear regression in n+1 dimensions:

- find a hyperplane that best describes the point dataset
- this plane is computed as a linear combination of parameters x_i:

$$y = a_1x_1 + a_2x_2 + \dots + a_nx_n + b$$

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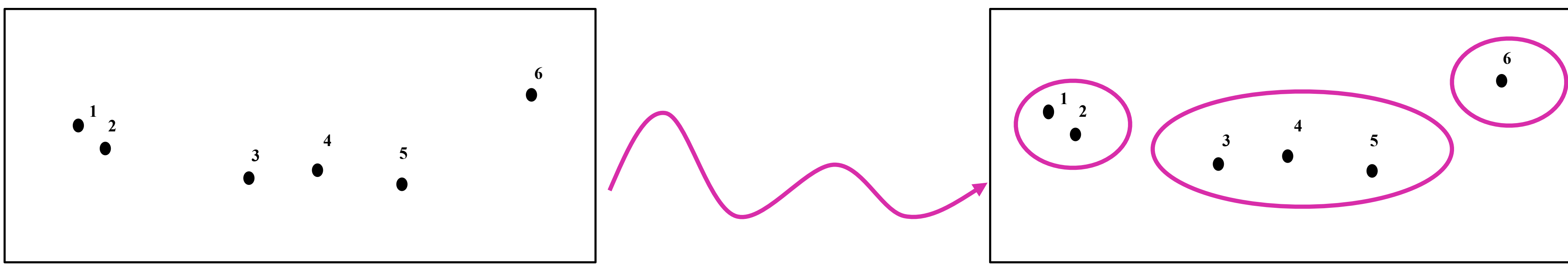
Cluster analysis

Clustering: unsupervised classification of data instances into groups/ clusters according to similarity.

Clustering

Data:
a set of points in a n-dimensional space

Result: groups/ clusters of points, located near to each other (similar)



Examples:
- study of parameters that affect crime
- study of occurence of diseases, etc.

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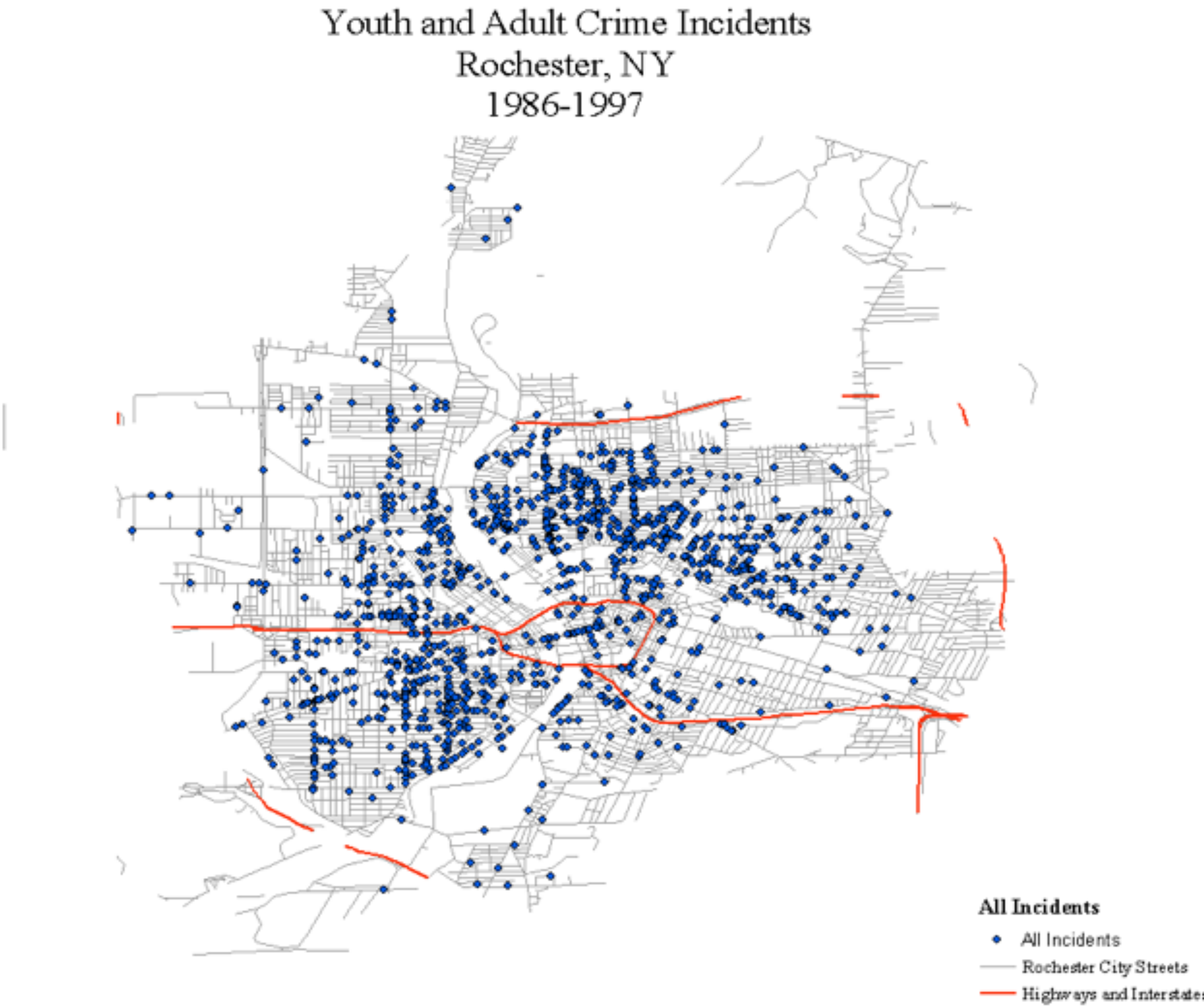
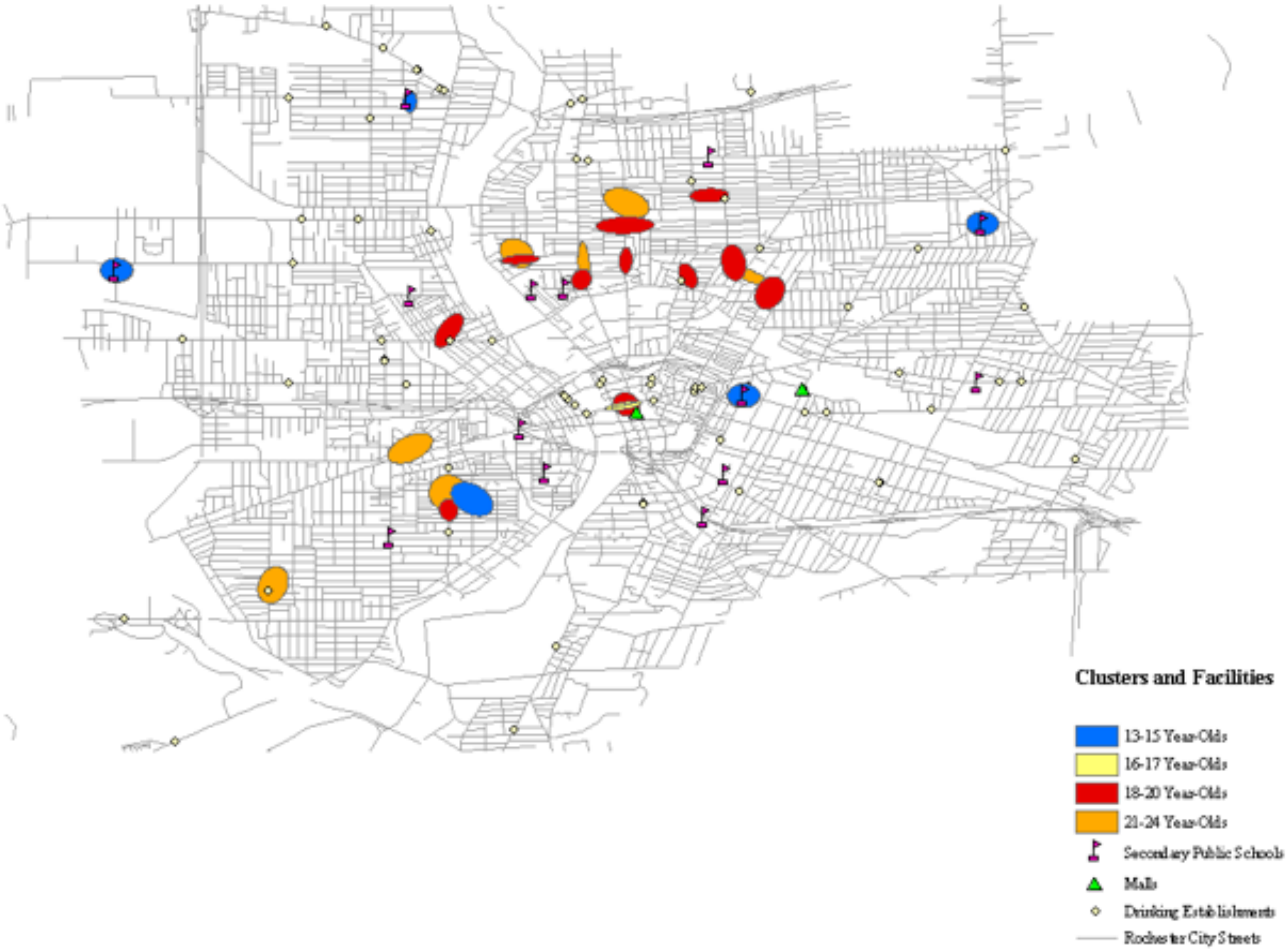


Hall GP and Lizette AJ, 2005, Offender Attributes and the Spatial Clustering of Crime Incidents: A Detailed Examination of Crime Hot Spots

First-Order Crime Clusters, Four Age Cohorts and Facilities
Rochester, NY
1986-1997



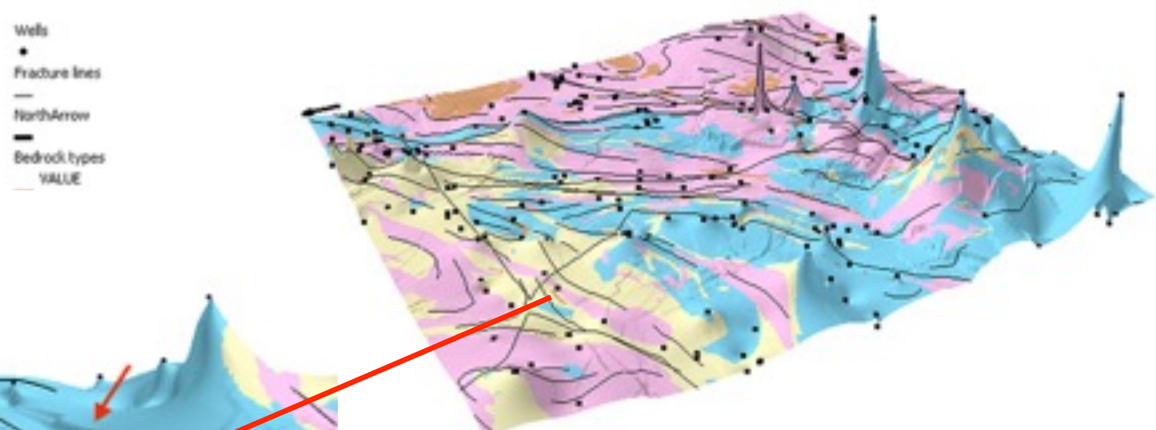
Hall GP and Lizette AJ, 2005, Offender Attributes and the Spatial Clustering of Crime Incidents: A Detailed Examination of Crime Hot Spots

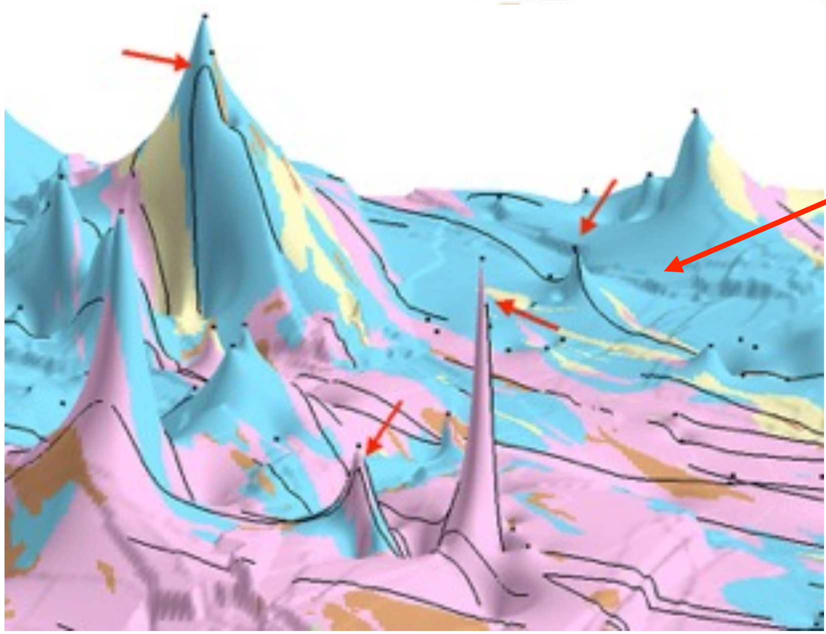
Using visualisation in data mining

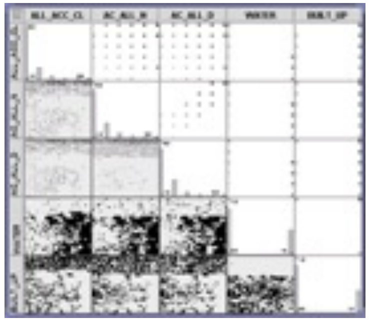
Visualisation

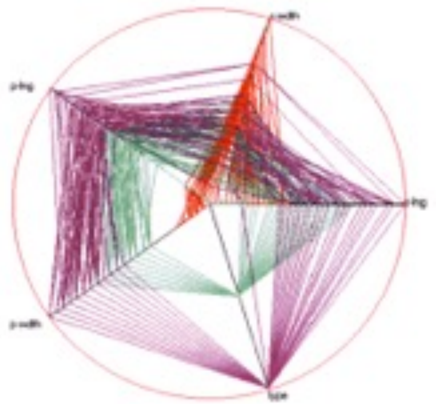
graphical communication of information

goal: present overview and summary of data, help to identify patterns and structures in the data





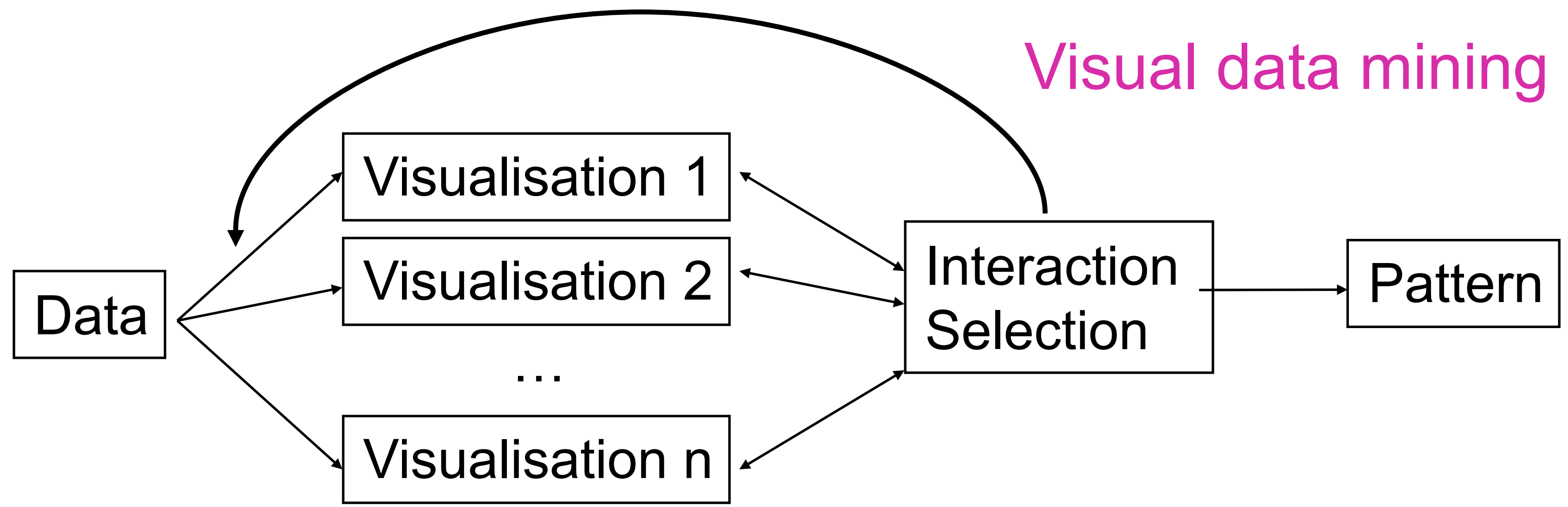


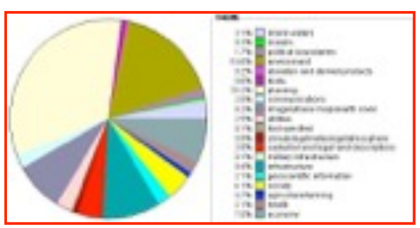


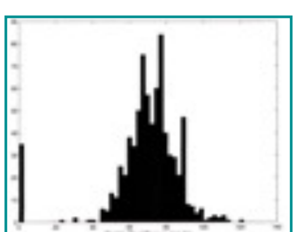
Visual data mining

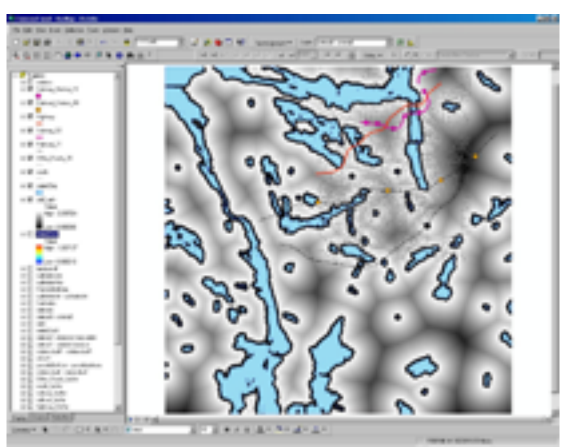
a step in the knowledge discovery process that uses visualisation as a communication channel between the user and the computer to discover new patterns

Visual data mining process

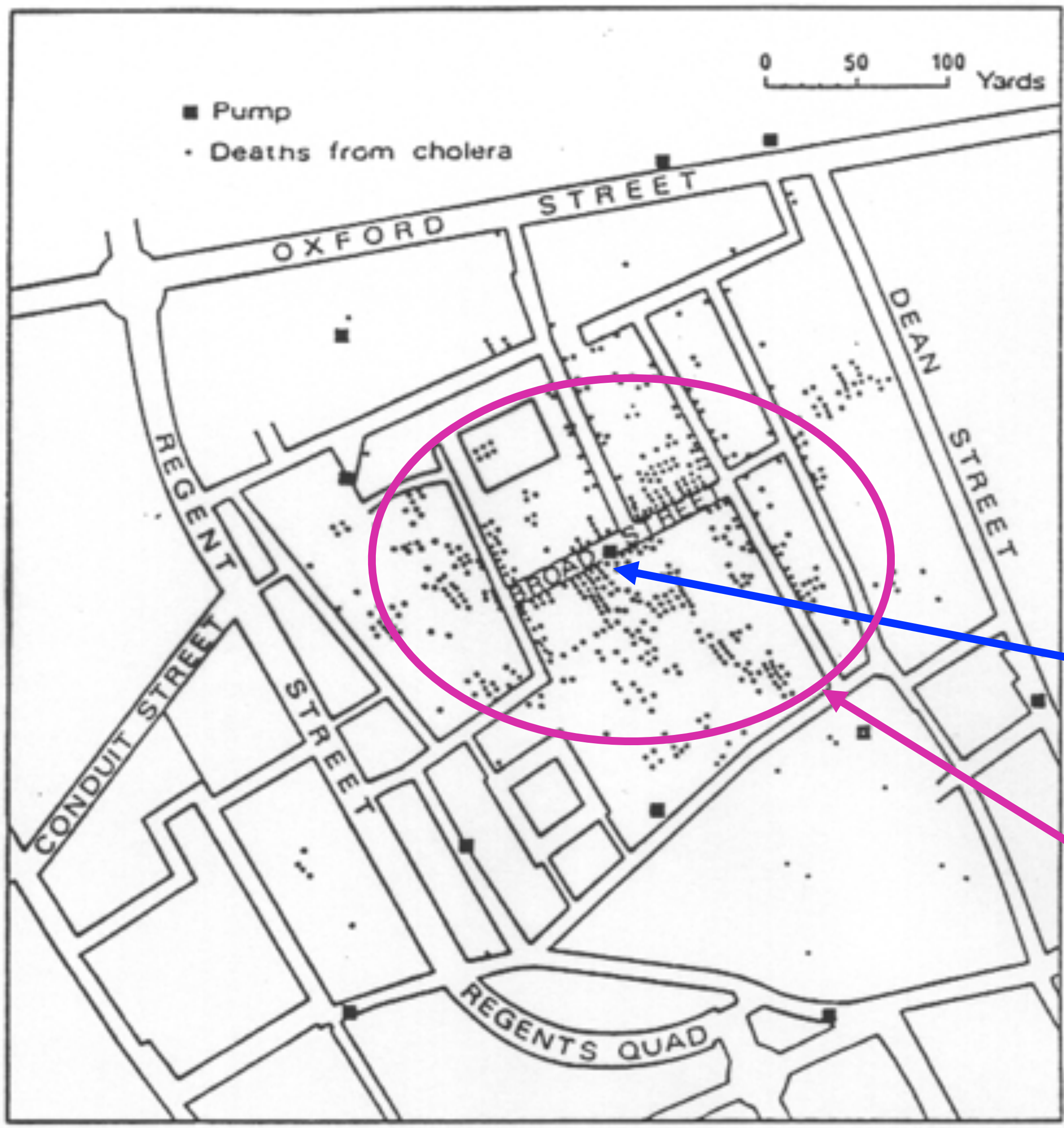








Dataanalys, Thomas Gumbricht, 2007



First attempt of visual analysis of spatial data:

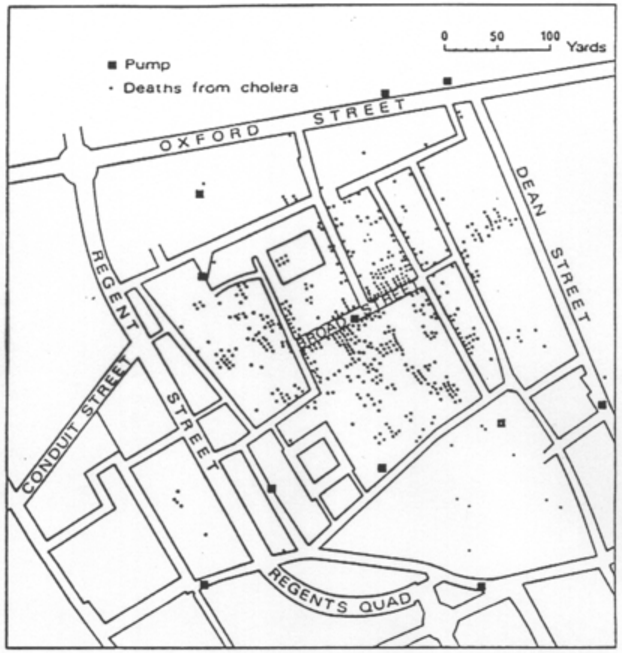
Dr. Snow's map of cholera outburst in London, 1855

Infected pump

High density of cholera deaths

The map shows the locations of cholera cases in the Soho area of London during an outbreak in the 1850s. The map indicated that the outbreak was centered on a pump in Broad Street, and provided evidence in support of Dr John Snow's hypothesis that contaminated water was causing the outbreak.

The Snow map



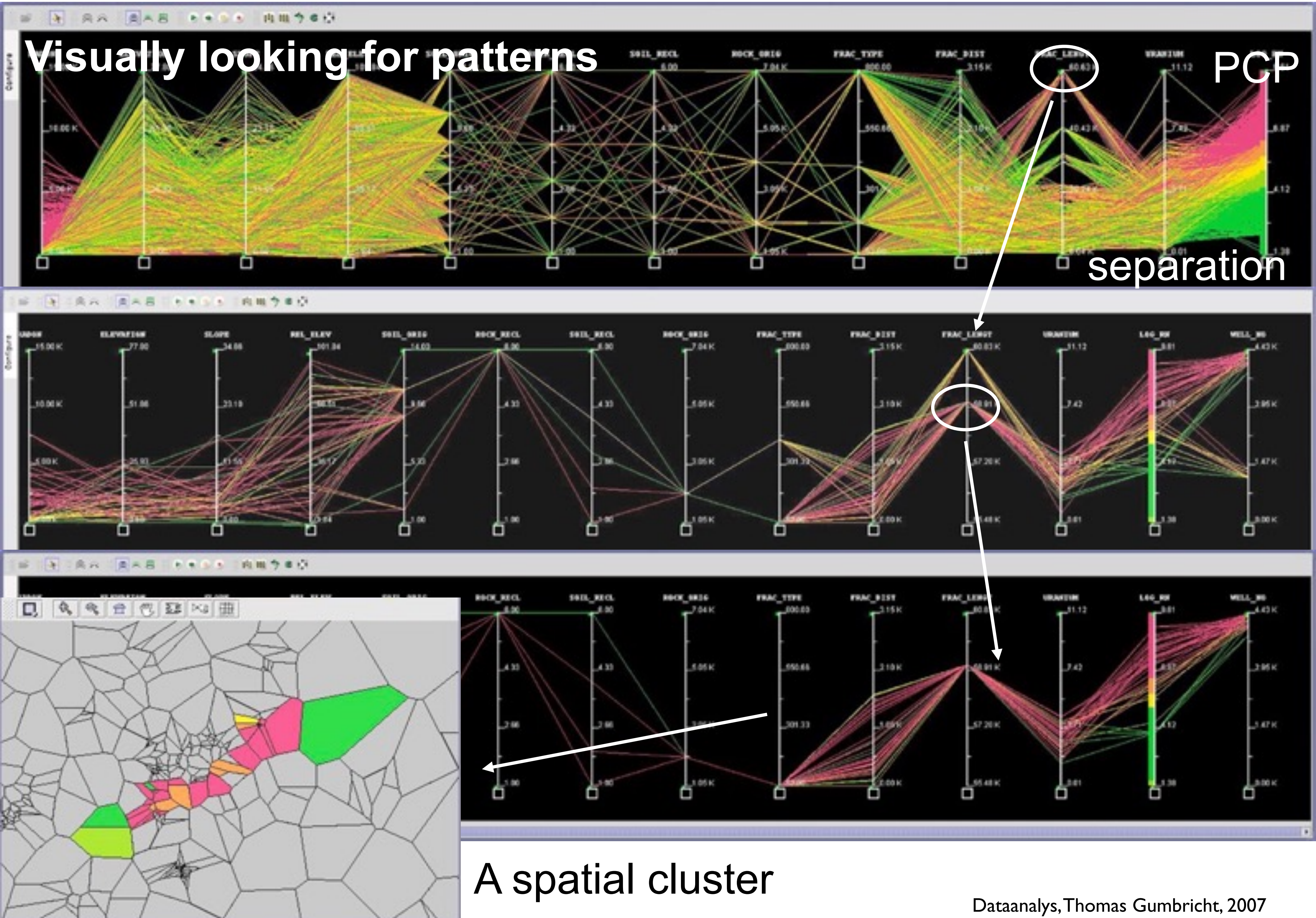
One of the first documented scientific examples of the **use of location to draw inferences**.

But the same cholera pattern could arise from air transmission:

- if the original carrier lived in the center of the outbreak
- air transmission was the hypothesis Snow was trying to disprove
- there were anomalies: deaths occurred in households that were closer to other sources of water, but Snow proved that people in these households also used the Broad street pump
- he removed the handle of the pump and cholera subsided

Today, a GIS could be used to show a sequence of maps as the outbreak developed:

- air transmission would produce a concentric sequence,
- drinking water a more randomly spreading sequence



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Comparison with topographical map