GEOG 413/613

LECTURE 10
Course Review

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Non-spatial Statistics

Measurement Concepts
- Precision
- Accuracy
- Validity
- Reliability

Classification Methods
- Equal intervals
- Quantile breaks
- Natural breaks

Presentation
- Histograms
- Frequency tables
- Scatter Plots
- Line Graphs

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Spatial Statistics

Central Tendency
- Mean Center
- Weighted Mean Center
- Median Center
- Manhattan Center

Dispersion
- Standard distance
- Relative Distance

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Non-spatial statistics

Central Tendency
- Mode
- Median
- Mean

Dispersion
- Deviation
- Average Deviation
- Range
- Standard Deviation
- Variance
- Covariance

Relative Position
- Kurstosis
- Skewness

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Analysis of Spatial Data

- Spatial autocorrelation
- The modifiable area unit problem
- Ecological fallacy
- Scale
- Non-uniformity of space
- Edge/boundary effects

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Geospatial Databases

- A database is an integrated set of data on a particular subject
  - Data are related and represent a specific aspect of the world
  - Data are for a specific purpose
- A geospatial database
  - Has entities (house, river, lake, road…)
  - Has attribute of these entities (location, size, type, name…)
  - Has spatial relationships (distances between entities, adjacency…)

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Geospatial Databases

- Advantages
  - Data stored at a single location reduces redundancy
    - Consider cadastral data needed by different levels of govt or departments
  - Maintenance costs decrease
  - Multiple applications and users can use the same data
    - Data are not dependent on software
  - Data sharing is easier
    - Multiple interfaces and operations
  - Data security and standards
- Disadvantages
  - The cost of acquiring DBMS software can be quite high
  - A DBMS can add unnecessary complexities for data management in small projects
  - Single-user GIS will often be better for files rather DBs

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DBMS

- Functions
  - A data model
  - Data input capability
  - Indexing
  - A query language
  - Security
  - Backup and recovery
  - Database administration tools
  - Applications
  - Application programming interfaces (APIs) for further customization

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DBMS Types and Extensions

- Types:
  - relational (RDBMS)
  - object (ODBMS)
  - object-relational (ORDBMS)
- Extensions
  - ORDBMS have spatial database extension
  - Indexing; Storage management; Transaction services; Query language; DB replication services; Query parser; Query optimizer

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Storing Geospatial Data in DBMS Tables

- Database tables are designed along the following principles
  - There is only one value in each cell at the intersection of a row and column.
  - All values in a column are about the same subject.
  - Each row is unique
  - There is no significance to the sequence of columns
  - There is no significance to the sequence of rows

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SQL

- SQL (Structured Query Language) programming language designed to retrieve sets (row and column combinations) of data from relational databases
- It is the standard database query language it has geographic capabilities
- Some DBMS can have proprietary SQL extensions that are usually only used on their system

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Database Design

- Database Design
  - Conceptual model
  - Logical model
  - Physical model
- Database Schema and Instances
  - the description of the database is called *database schema*
  - the data items that reside in a database at a specific point in time form the *database instance*

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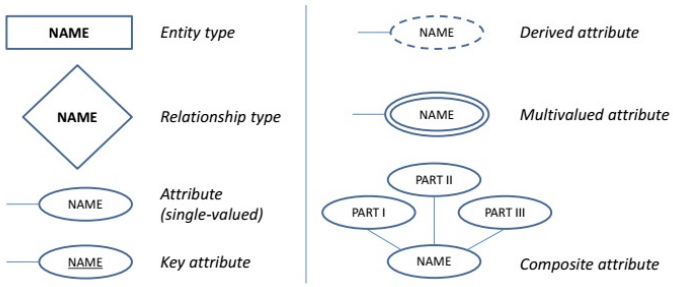
Entity-Relationship Model

- ER-model: diagrammatic representation of the *miniworld* into a set of entities and their relationships.



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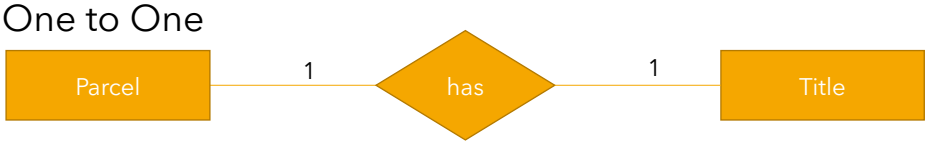
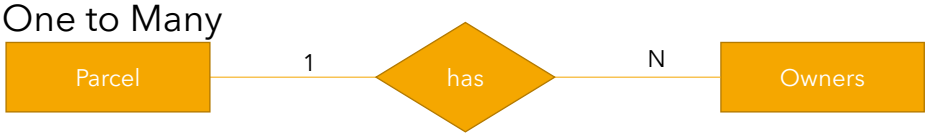
Entity and Relationship Types

- One to One



- One to Many



- Many to Many

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Normalization

- The process minimizing redundancy in a database
  - Characterizes the level of redundancy in a relational schema
  - Provides mechanisms for transforming schemas in order to remove redundancy
  - Data normalization follows certain rules which are categorized as "normal forms". There are 6 normal forms but we'll briefly look at only 3
- In principle, any information that can be applied to more than one record should be moved to its own table.
  - Each successive normal form applied must meet the rules of the previous form

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Indexing Geographic Information

- A database index is a special representation of information about objects that improves searching
  - B-tree indexing
  - Grid indexing
  - Quadtree indexing
  - R tree

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Editing and Data Maintenance

- Transaction
- Versioning

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GeoWeb

- Web GIS
  - web service technology
    - Key elements:
      - A server and a client
      - The server performs the requested GIS operations and sends responses to the client via HTTP.
      - The format of the response sent to the client can be in many formats, such as HTML, binary image, XML, JSON, etc

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Web GIS Advantages

- A wide reach
- A wide user base
- Cross-platform capability
- Low cost (relative to potential usage)
- Easy to use
- Unified updates
- Numerous applications

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Essential elements of a web GIS **application**

- A web application
  - Software to visualize and interact with geographic information
- Digital basemaps
  - Geographic context for each application e.g. Transportation, Topographic, Terrain, Imagery
- Operational layers
  - Additional layers for the operation e.g. sensor feeds, editing layers
- Tasks and tools in the web GIS application
  - Client tasks, server tasks
- One or more geospatial databases

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4 Broad Themes of Big Data

- Information
  - Data are created, shared and utilised extensively in recent times
  - The proliferation of personal mobile devices
    - connected to the Internet
    - equipped with digital sensors
  - Expanding variety in form
- Pervasive (Wide impact)
  - Many fields
    - Examples: Elections; Google searches linked to epidemiology and economics

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4 Broad Themes of Big Data

- Technology
  - Needs intensive computational and storage specs
  - Hadoop
    - Open source parallel computing.
    - Google, Yahoo, FaceBook
- Methods of Analysis
  - cluster analysis; genetic algorithms; natural language processing; machine learning; neural networks; predictive modelling; regression models; social network analysis; sentiment analysis; signal processing and data visualisation

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Landscape Metrics

- Pattern and Process
  - Processes in natural systems
    - Spatial pattern (form) can influence process
  - Spatial patterns
    - Formed from processes
    - Patterns tell us about process
  - Quantifying the complexity of nature
    - measure ecological functioning (e.g. biodiversity, connectivity)
    - measure land use processes (land consumption, fragmentation, urban sprawl)

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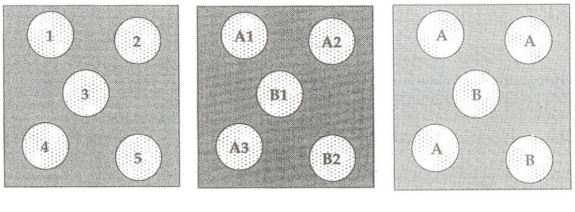
Landscape Metrics



Patch level | Class level | Landscape level

Farina, A. 2000. Landscape ecology in action. Kluwer Academic Publishers, Netherlands

Patch-level metrics are defined for individual patches, and characterize the spatial character and context of patches.

Class-level metrics are integrated over all the patches of a given type (class).

Landscape-level metrics are integrated over all patch types or classes over the full extent of the data (i.e., the entire landscape).

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Landscape Metrics

Composition

- Proportional Abundance
- Richness
- Diversity
- Evenness

Configuration

- Patch size distribution and density:
- Patch shape complexity:
- Core Area
- Isolation/Proximity:
- Contrast
- Dispersion
- Contagion and Interspersion
- Subdivision
- Connectivity

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Sampling Methods

- Provides knowledge about a whole population
  - i.e. make inference about a population from the sample data
- Larger sample sizes are more accurate representations of the whole
  - Large samples are costly: time, labour
    - Can be wasteful since we can statistically infer from appropriate samples
- A sampling strategy with the minimum bias is the most statistically valid

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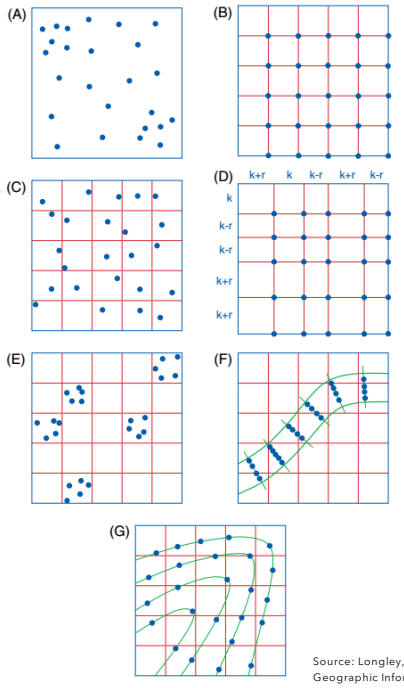
Sampling Methods



Spatial sample designs: (A) simple random sampling, (B) systematic sampling, (C) stratified random sampling, (D) stratified sampling with random variation in grid spacing, (E) clustered sampling, (F) transect sampling, and (G) contour sampling.

Source: Longley, Paul A.; Goodchild, Michael F.; Maguire, David J.; Rhind, David W.. Geographic Information Science and Systems, 4th Edition. Wiley.

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Random Sampling

- Random sampling: each member of the population has an equal chance of being selected
  - Advantages:
    - Can be used with large sample populations
    - Avoids bias
  - Disadvantages:
    - Can disproportionately represent some parts of the population at the expense of others

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Systematic Sampling

- Systematic Sampling: Samples are chosen at regular intervals
  - Sample locations are evenly distributed for example every two metres along a transect line
    - systematic sampling implies a regularly spaced grid
      - Advantages:
        - It is more straight-forward than random sampling
        - Provides a good coverage of the study area
      - Disadvantages:
        - It is more biased: not all points have an equal chance of being selected
        - It may lead to over or under representation if there is periodicity in the data (e.g. sampling at the same interval as the location of erosion barriers along a beach. Or a city road grid)

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Stratified sampling

- Stratified sampling: used when the parent population is made up of sub-groups that of interest.
  - Divide the sampling design into strata(classes), and then select a sample from each stratum
  - The strata are defined so that individuals inside each class are similar based on the characteristic believed to influence the phenomena

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Stratified sampling

- Advantages:
  - If the proportions of the subgroups are known, the results are representative of the whole population
  - Correlations and comparisons can be made between subgroups
- Disadvantages:
  - The proportions of the subgroups must be known

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Levels or Scales of Measurement

- Nominal
  - Categorical data e.g. land use type, religious affiliation
- Ordinal
  - Ranked data , e.g. main, secondary, minor roads
- Interval:
  - Interval between any two units can be measured on scale. Zero value is assigned arbitrarily e.g. Celsius and Fahrenheit scales (80°F is not twice as hot as 40°F)
- Ratio:
  - interval data with an absolute zero value

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Multivariate Exploratory Data Analysis

- the initial investigations on data
  - discover patterns
  - Reduce dimensions
  - identify anomalies/outliers
  - test hypothesis (e.g. observed vs expected)
  - check assumptions
    - Descriptive statistics
    - Visualization

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Multivariate Exploratory Data Analysis

- Common Tools
  - Histogram
  - Box plot
  - Scatter plot matrix
  - Bar graph
  - Parallel Coordinate Plots

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Dimensionality Reduction

- Data dimension is the number of variables for a measured theme/dataset
- Data with a high dimensionality is difficult to visualize
- Reducing the dimensionality of the data helps understand the intrinsic aspects of the dataset
  - Find structure within features
  - Aid in visualization
- The methods maximize information while minimizing differences between the original data and the new lower dimensional representation
- Principal Component Analysis is one such method

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Principal Component Analysis

- Widely used method for dimensionality reduction
- The transformation between original data and the new lower dimensional representation is a linear projection
  - find a linear combination of the original features principal components.
  - The principal components will maintain as much as is possible the same variance as the original data
  - The principal components are uncorrelated (orthogonal)

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Principal Component Analysis

- PCA major steps
  - Standardize the variables
    - Centre (deviation from the mean)
    - Scale (divide the deviation by the standard deviation)
  - Calculate the covariance matrix
    - Covariance – how 2 variables vary with each other
    - If you have more than 2 variables, then you gave more than one covariance (given variables x,y,z –> cov(x,y), cov(x,z), cov(y,z))
  - Calculate the eigenvectors and eigenvalues of the covariance matrix

$$Av = \lambda v$$

$$A - matrix$$
$$v - eigenvector\ for\ \lambda$$
$$\lambda - eigenvalue\ for\ v$$

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Cluster Analysis

- To reduce data complexity by sorting the data into subsets (clusters) that share some common trait
- Achieve the reduction of observations by minimizing the within-group variation and maximizing the between group variation (i.e. the degree of association between two objects is maximal if they belong to the same group and minimal otherwise)

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Clustering Analysis

- Searching for groups in the data in such a away that objects belonging to the same cluster resemble each other, whereas objects in different clusters are dissimilar.
- Two methods are partitioning and hierarchical clustering

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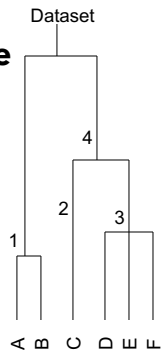
Cluster Analysis

- Hierarchical Methods
  - Can be **agglomerative** or **divisive**



Dendogram

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Cluster Analysis

- Hierarchical Methods
  - Identifies homogeneous groups of variables by using an algorithm that:
    - either starts with each observation in a separate cluster and combines clusters until only one is left (agglomerative),
    - or starts with the whole dataset and proceeds to divide it into successively smaller clusters (divisive).

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Cluster Analysis: K-means

- Partitioning Methods
  - Based on specifying an initial number of groups, and iteratively reallocating observations between groups until some equilibrium is attained
  - The most popular method of partitioning is the *k-means* method
  - commonly used as an unsupervised machine learning algorithm for partitioning a given data set into a set of *k* groups
    - *k* represents the number of non-overlapping groups (clusters) specified by the user

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K-Means Analysis

- K-Means Clustering
  - Group membership is determined be calculating the centroid for each group, then assigning each observation to the group with the nearest centroid
  - The primary objective in k-means clustering is to define clusters so that the total **within-cluster variation** is minimized and the **between group variation** is maximized

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Point Pattern Analysis

- Examining the spatial arrangement of point locations on the landscape
- Two methods are ***nearest neighbour analysis*** and ***quadrat analysis***.
  - Standardized Nearest Neighbour Index
  - Variance-Mean Ratio

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Measures of Spatial Autocorrelation

- Moran's I Statistic
  - A global spatial autocorrelation measure that calculates the relationship between locations of observations (w_{ij}) the similarity between the attributes (c_{ij}) at those locations
- Local Indicators of Spatial Association
  - G-Statistic (Getis-Ord's)for Measuring High/Low Clustering

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Bivariate Regression

- Bivariate Analysis
  - Two variables are explored in detail
  - Assumption is that one variable influences/affects the other
    - Independent Variable (Explanatory Variable)
      - The variable creating the influence/effect
    - Dependent Variable
      - The variable receiving the influence or effect

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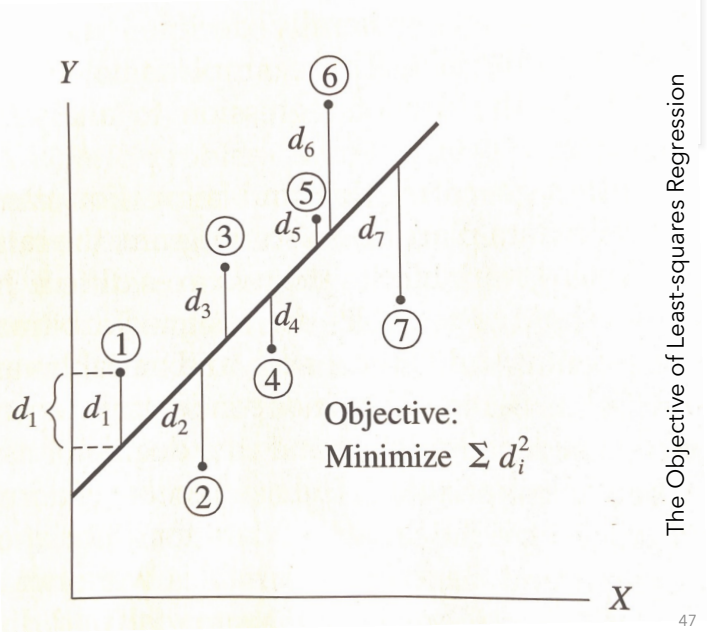
Bivariate Regression Line

- The least-squares regression line is unique
  - Minimizes the sum of the squared vertical distances between each data point and the line
- The regression is given by the straight-line equation
  $Y = a + bX$
- *a* is the intercept on the Y-Axis
  - Represents the value of Y when X is zero
- *b* represents the slope of the line
  - Also, the correlation coefficient



The Objective of Least-squares Regression

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