Introduction to Web Data Mining: Data

Outline

- Attributes and Objects
- Types of Data
- Data Quality
- Data Preprocessing

Quick Questions

- What are the most time consuming part in DM?

  Data Preprocessing

- What are the most important steps for finishing a given DM task?

  Data Understanding and Preprocessing

  Domain Knowledge Discovery

  Visualization

  Algorithm

Simple Comparison

Medical Care		**Data Mining**	
First Concern		First Concern	
Patient & symptoms	**Medicine**	Data & Applications	**Algorithms**

What is Data

- Collection of data objects and their attributes （属性）
- An attribute is a property or characteristic of an object
  - Examples: eye color of a person, temperature, etc.
  - Attribute is also known as variable, field, characteristic, or feature
- A collection of attributes describe an object
  - Object is also known as record, point, case, sample, entity, or instance

Attributes

Objects

Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	125K	No
2	No	Married	100K	No
3	No	Single	70K	No
4	Yes	Married	120K	No
5	No	Divorced	95K	Yes
6	No	Married	60K	No
7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes

Attributes

- Attribute (or dimensions, features, variables): a data field, representing a characteristic or feature of a data object.
  - *E.g., customer _ID, name, address*

Attribute Values

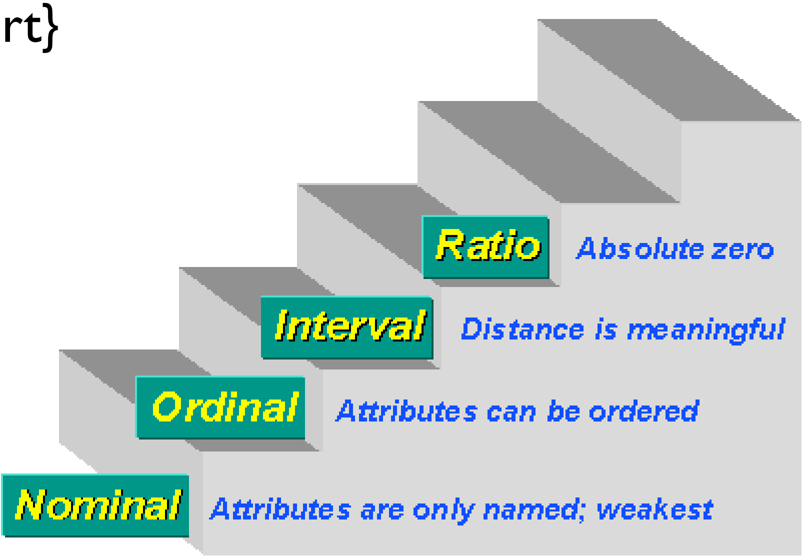
- Attribute values are numbers or symbols assigned to an attribute for a particular object

- Distinction between attributes and attribute values
  - Same attribute can be mapped to different attribute values
    - Example: height can be measured in feet or meters

  - Different attributes can be mapped to the same set of values
    - Example: Attribute values for ID and age are integers
    - But properties of attribute values can be different

Types of Attributes

- There are different types of attributes
  - Nominal （标称）
    - Examples: ID numbers, eye color, zip codes
  - Ordinal （序数）
    - Examples: rankings (e.g., taste of potato chips on a scale from 1-10), grades, height in {tall, medium, short}
  - Interval （区间）
    - Examples: calendar dates, temperatures in Celsius or Fahrenheit.
  - Ratio （比例）
    - Examples: temperature in Kelvin, length, time, counts



Discrete and Continuous Attributes

- Discrete Attribute
  - Has only a finite or countably infinite set of values
    - E.g. , zip codes, counts, or the set of words in a collection of documents
  - Often represented as integer variables.
  - Note: **binary attributes** are a special case of discrete attributes
    - Nominal attribute with only 2 states (0 and 1)
    - Symmetric binary: both outcomes equally important
      - □ e.g., gender
    - Asymmetric binary: outcomes not equally important
      - □ e.g., medical test (positive vs. negative)
      - □ Convention: assign 1 to most important outcome (e.g., HIV positive)

- Continuous Attribute
  - Has real numbers as attribute values
    - E.g.:, temperature, height, or weight.
  - Practically, real values can only be measured and represented using a finite number of digits.
  - Continuous attributes are typically represented as floating-point variables.

Important Characteristics of Structured Data

- Dimensionality
  - Curse of Dimensionality
- Sparsity
  - Only presence counts
- Resolution
  - Patterns depend on the scale

Types of data sets

- Record
  - Relational records
  - Data matrix, e.g., numerical matrix, crosstabs
  - Document data: text documents: term-frequency vector
  - Transaction data
- Graph and network
  - World Wide Web
  - Social or information networks
  - Molecular Structures
- Ordered
  - Video data: sequence of images
  - Temporal data: time-series
  - Sequential Data: transaction sequences
  - Genetic sequence data
- Spatial, image and multimedia:
  - Spatial data: maps
  - Image data:
  - Video data:

Record Data

- Data that consists of a collection of records, each of which consists of a fixed set of attributes

Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	125K	**No**
2	No	Married	100K	**No**
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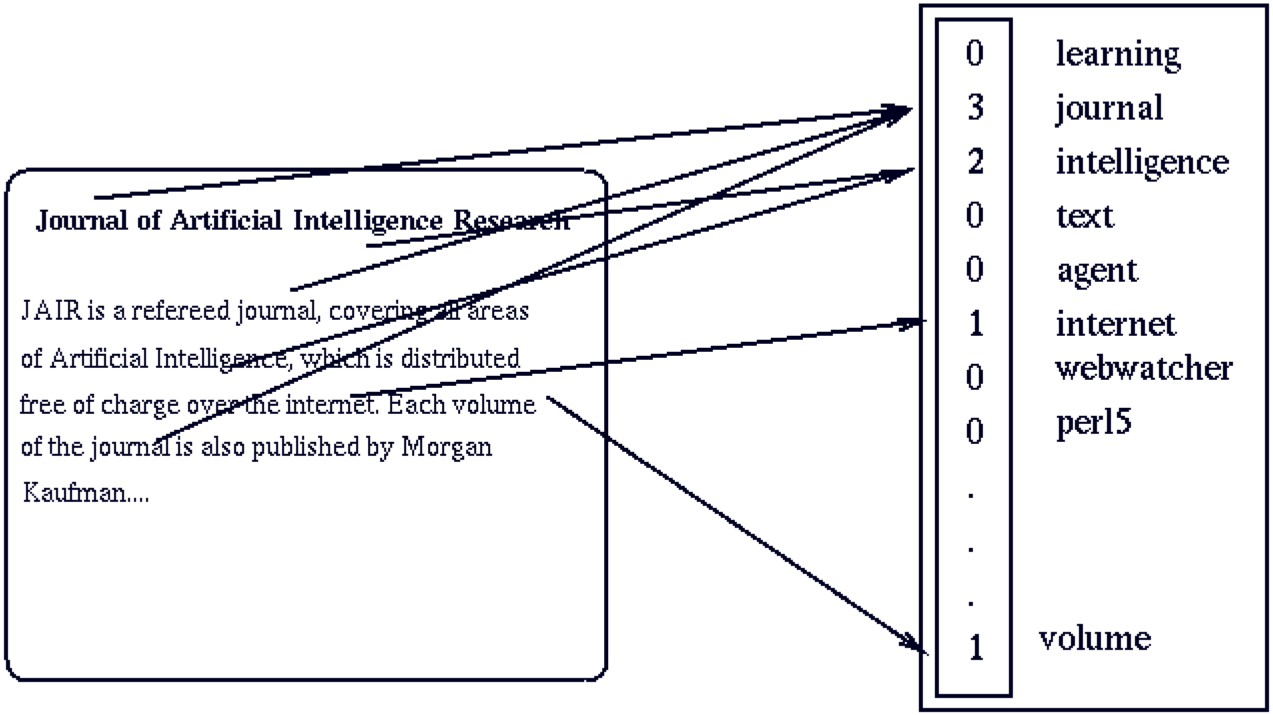
8	No	Single	85K	**Yes**
9	No	Married	75K	**No**
10	No	Single	90K	**Yes**

Document Data



Journal of Artificial Intelligence Research

JAIR is a refereed journal, covering all areas of Artificial Intelligence, which is distributed free of charge over the internet. Each volume of the journal is also published by Morgan Kaufman....

0	learning
3	journal
2	intelligence
0	text
0	agent
1	internet
0	webwatcher
0	perl5
.	
.	
.	
1	volume

Bag-of-words

Document Data

- Each document becomes a `term' vector,
  - each term is a component (attribute) of the vector,
  - the value of each component is the number of times the corresponding term occurs in the document.

	team	coach	play	ball	score	game	win	lost	timeout	season
Document 1	3	0	5	0	2	6	0	2	0	2
Document 2	0	7	0	2	1	0	0	3	0	0
Document 3	0	1	0	0	1	2	2	0	3	0

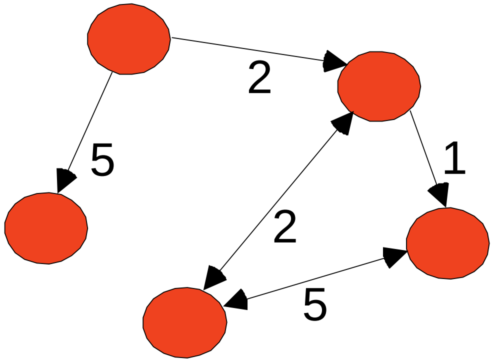
Transaction Data

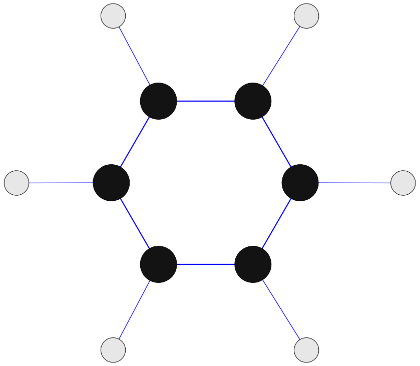
- A special type of record data, where
  - each record (transaction) involves a set of items.
  - For example, consider a grocery store. The set of products purchased by a customer during one shopping trip constitute a transaction, while the individual products that were purchased are the items.

TID	*Items*
1	Bread, Coke, Milk
2	Beer, Bread
3	Beer, Coke, Diaper, Milk
4	Beer, Bread, Diaper, Milk
5	Coke, Diaper, Milk

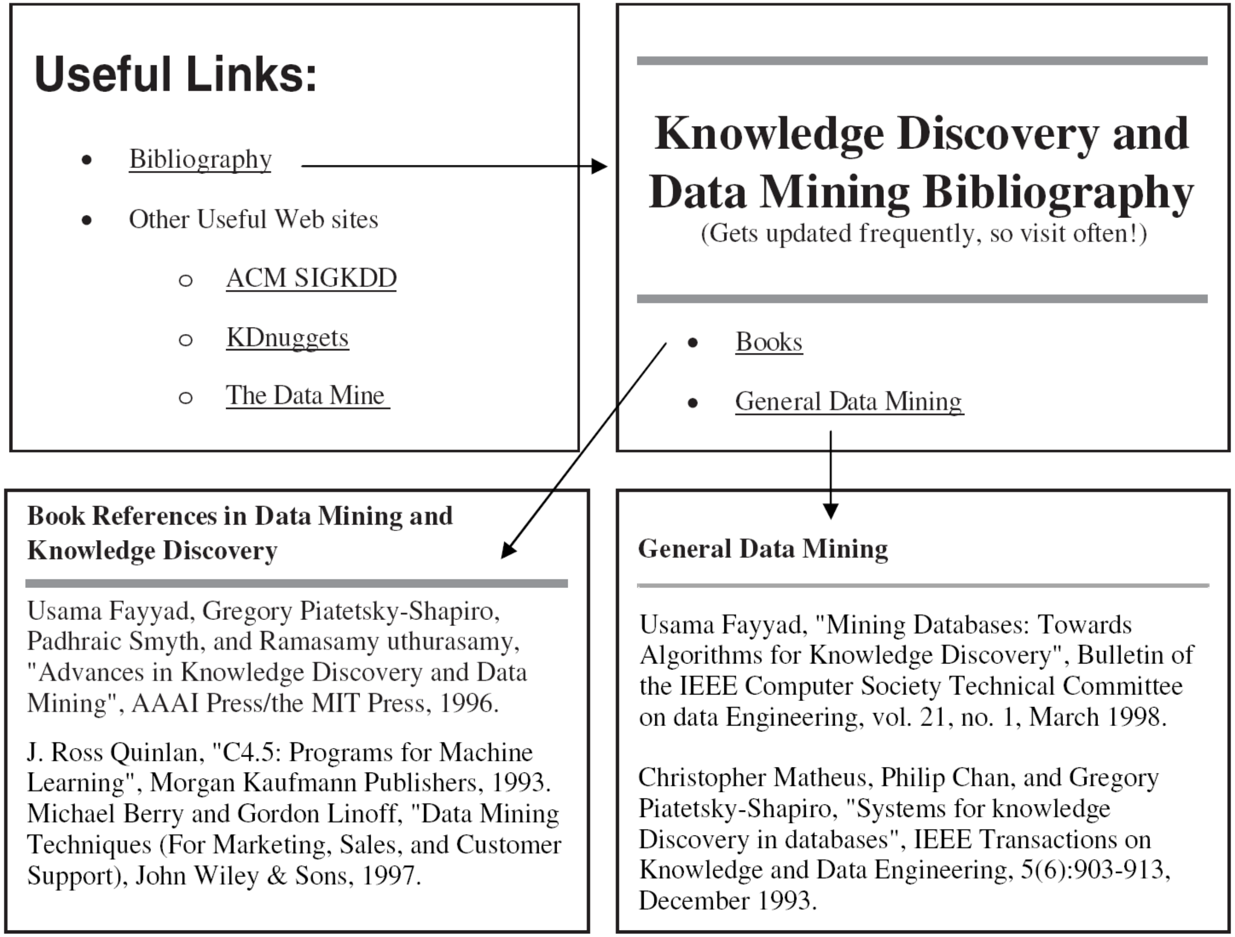
Graph Data

- Examples: Generic graph, a Molecule, and Webpages





Benzene Molecule: C6H6



Useful Links:

- Bibliography
- Other Useful Web sites
  - ACM SIGKDD
  - KDnuggets
  - The Data Mine

Knowledge Discovery and Data Mining Bibliography

(Gets updated frequently, so visit often!)

- Books
- General Data Mining

Book References in Data Mining and Knowledge Discovery

Usama Fayyad, Gregory Piatetsky-Shapiro, Padhraic Smyth, and Ramasamy uthurasamy, "Advances in Knowledge Discovery and Data Mining", AAAI Press/the MIT Press, 1996.

J. Ross Quinlan, "C4.5: Programs for Machine Learning", Morgan Kaufmann Publishers, 1993. Michael Berry and Gordon Linoff, "Data Mining Techniques (For Marketing, Sales, and Customer Support), John Wiley & Sons, 1997.

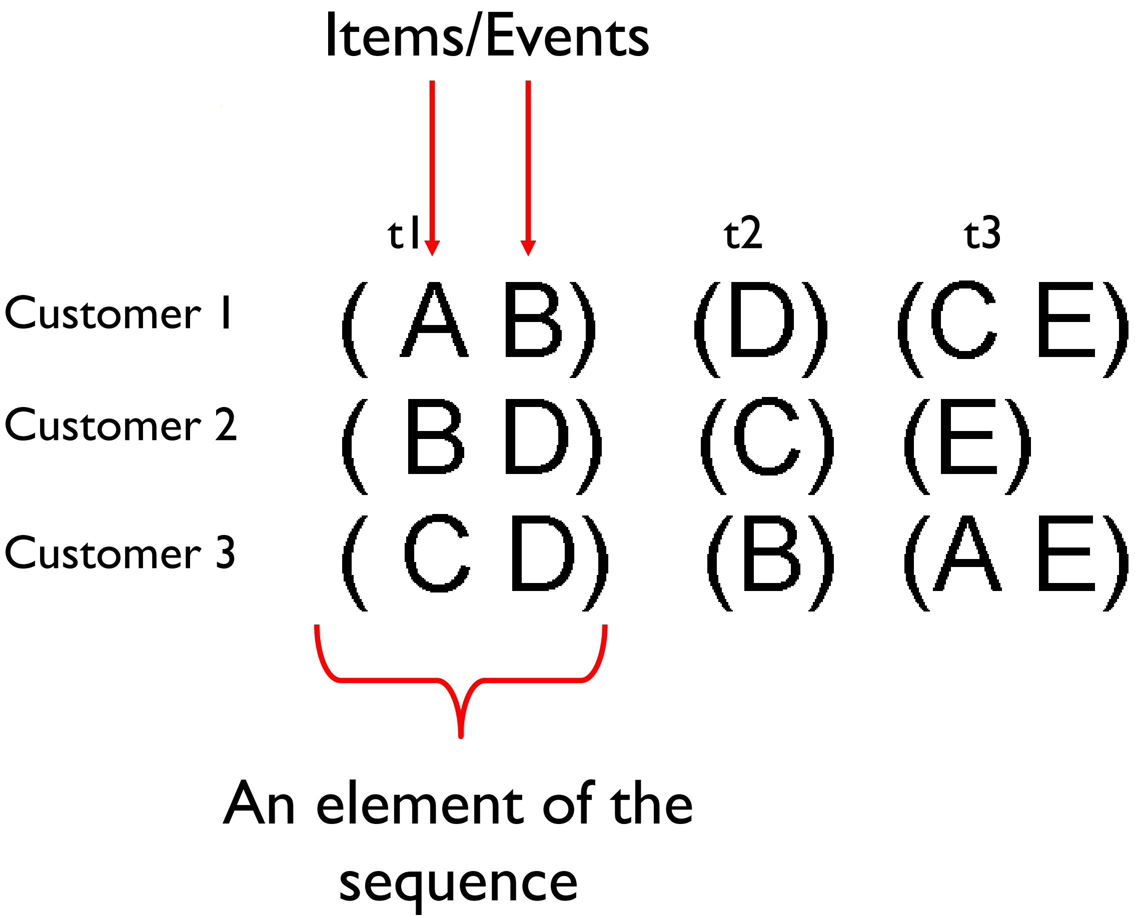
General Data Mining

Usama Fayyad, "Mining Databases: Towards Algorithms for Knowledge Discovery", Bulletin of the IEEE Computer Society Technical Committee on data Engineering, vol. 21, no. 1, March 1998.

Christopher Matheus, Philip Chan, and Gregory Piatetsky-Shapiro, "Systems for knowledge Discovery in databases", IEEE Transactions on Knowledge and Data Engineering, 5(6):903-913, December 1993.

Ordered Data

- Sequences of transactions



Items/Events

	t1	t2	t3
Customer 1	(A B)	(D)	(C E)
Customer 2	(B D)	(C)	(E)
Customer 3	(C D)	(B)	(A E)

An element of the sequence

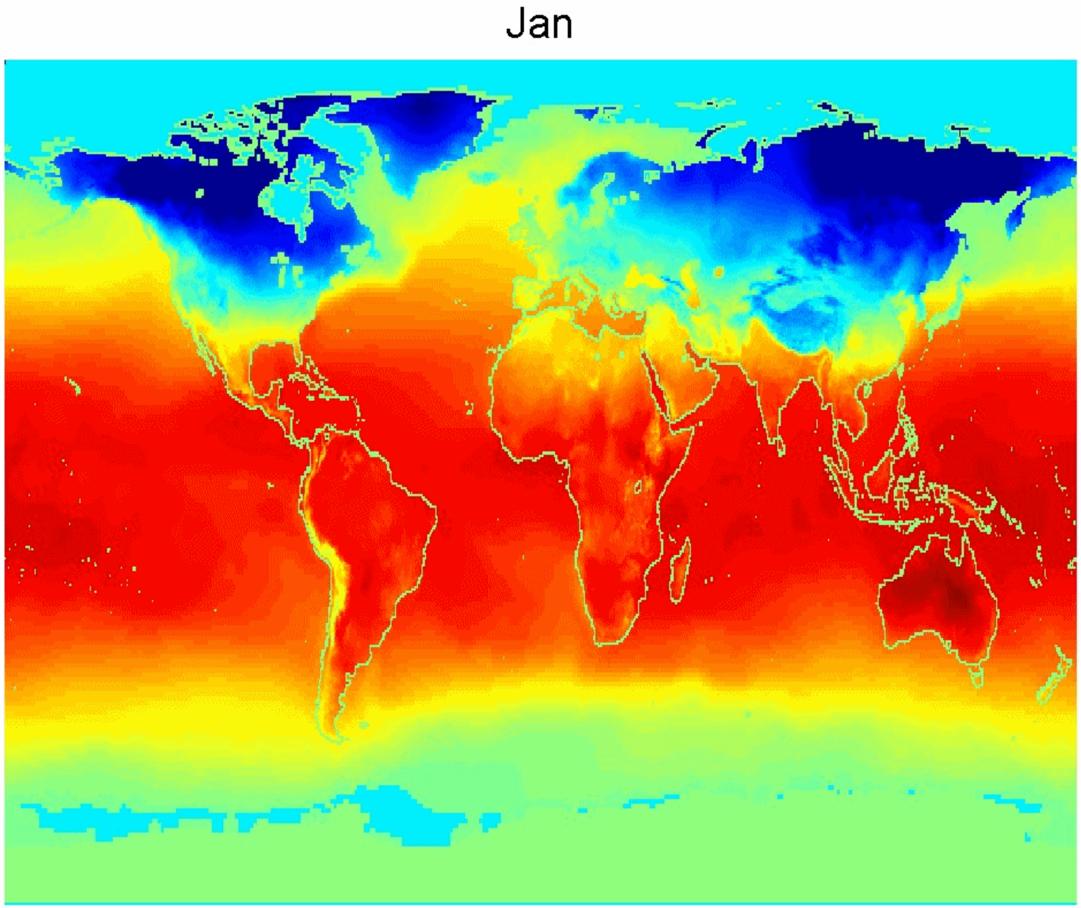
Ordered Data

- Genomic sequence data

```
GGTTCCGCCTTCAGCCCCGCGCC
CGCAGGGCCCGCCCCGCGCCGTC
GAGAAGGGCCCGCCTGGCGGGCG
GGGGGAGGCGGGGCCGCCCGAGC
CCAACCGAGTCCGACCAGGTGCC
CCCTCTGCTCGGCCTAGACCTGA
GCTCATTAGGCGGCAGCGGACAG
GCCAAGTAGAACACGCGAAGCGC
TGGGCTGCCTGCTGCGACCAGGG
```

Spatial Data

- Spatio-Temporal Data



Average Monthly Temperature of land and ocean

Data Quality

- Poor data quality negatively affects many data processing efforts
  - “The most important point is that poor data quality is an unfolding disaster. Poor data quality costs the typical company at least ten percent (10%) of revenue; twenty percent (20%) is probably a better estimate.”

—Thomas C. Redman, DM Review, August 2004

- Data mining example: a classification model for detecting people with loan risks is built using poor data
  - Some credit-worthy candidates are denied loans
  - More loans are given to individuals that default

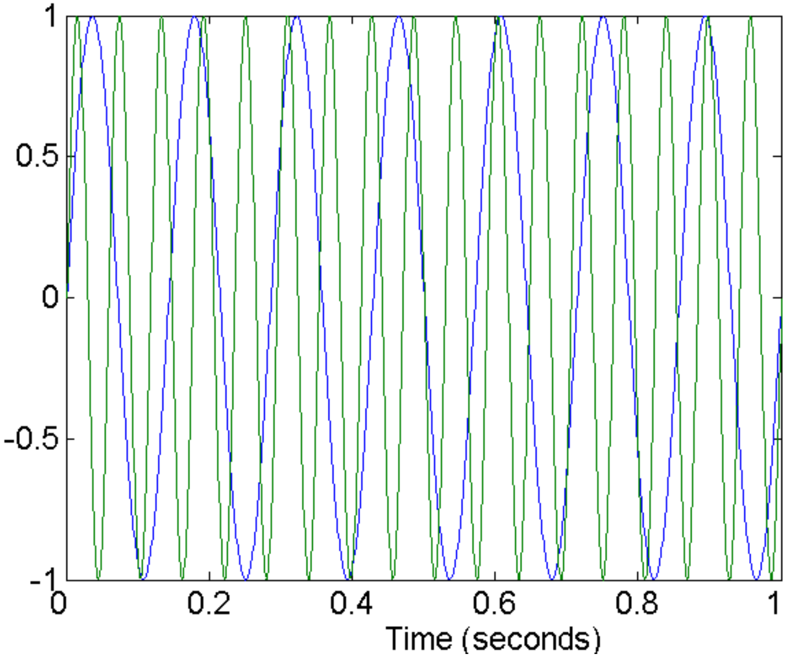
Data Quality …

- What kinds of data quality problems?
- How can we detect problems in the data?
- What can we do about these problems?

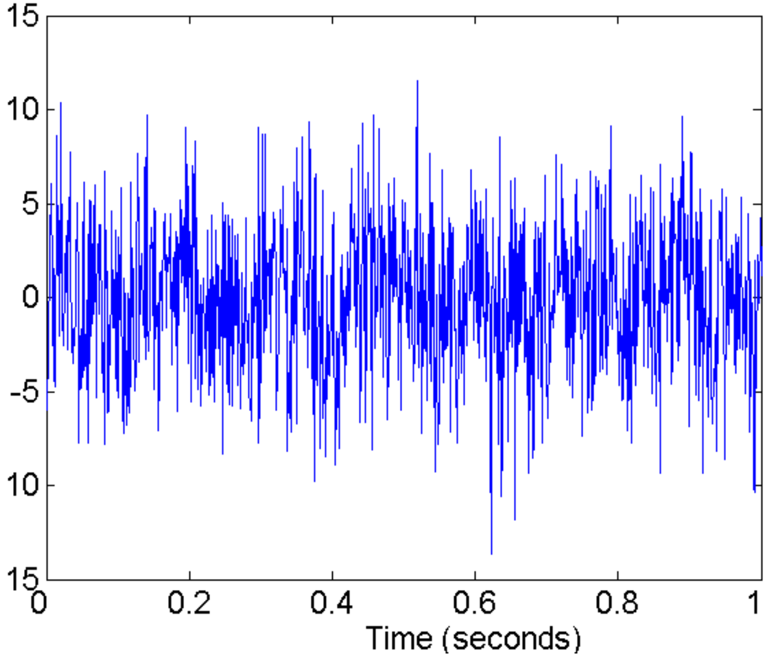
- Examples of data quality problems:
  - Noise and outliers
  - Missing values
  - Duplicate data

Noise

- Noise refers to modification of original values
  - Examples: distortion of a person's voice when talking on a poor phone and "snow" on television screen



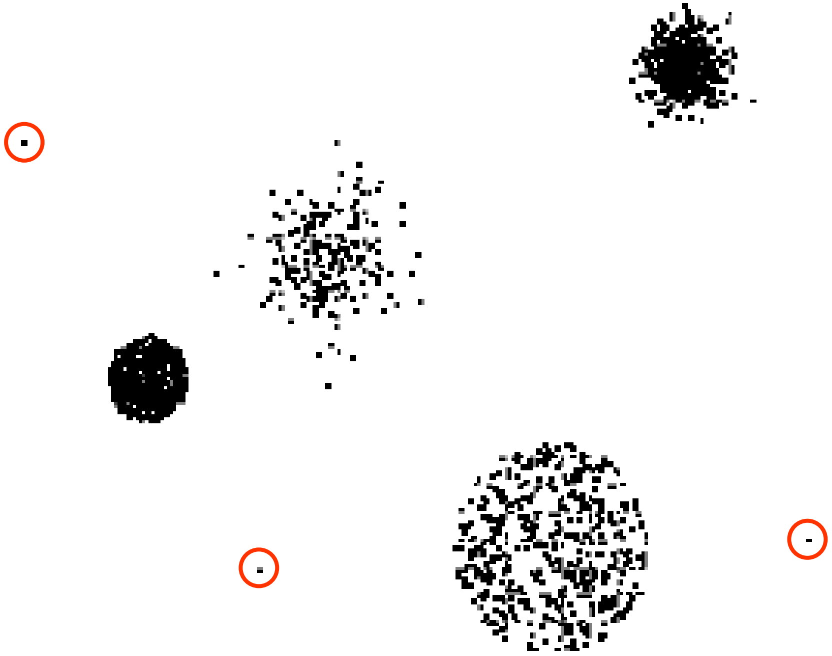
Two Sine Waves



Two Sine Waves + Noise

Outliers

- Outliers are data objects with characteristics that are considerably different than most of the other data objects in the data set
  - Case 1: Outliers are noise that interferes with data analysis
  - Case 2: Outliers are the goal of our analysis
    - Credit card fraud
    - Intrusion detection



Missing Values

- Reasons for missing values
  - Information is not collected
    (e.g., people decline to give their age and weight)
  - Attributes may not be applicable to all cases
    (e.g., annual income is not applicable to children)

- Handling missing values
  - Eliminate data objects
  - Estimate missing values
    - Example: time series of temperature
    - Example: census results
  - Ignore the missing value during analysis

Duplicate Data

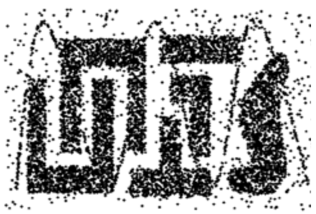
- Data set may include data objects that are duplicates, or almost duplicates of one another
  - Major issue when merging data from heterogeneous sources

- Examples:
  - Same person with multiple email addresses

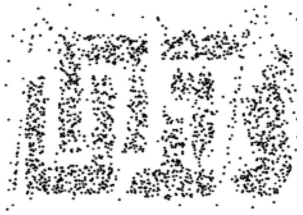
- Data cleaning
  - Process of dealing with duplicate data issues

Data Preprocessing

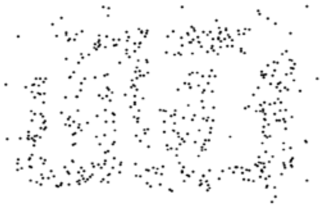
- Aggregation
- Sampling
- Dimensionality Reduction
- Feature subset selection
- Feature creation
- Discretization and Binarization
- Attribute Transformation



8000 points



2000 Points



500 Points

Aggregation

- Combining two or more attributes (or objects) into a single attribute (or object)

- Purpose
  - Data reduction
    - Reduce the number of attributes or objects
  - Change of scale
    - Cities aggregated into regions, states, countries, etc
  - More "stable" data
    - Aggregated data tends to have less variability

Sampling

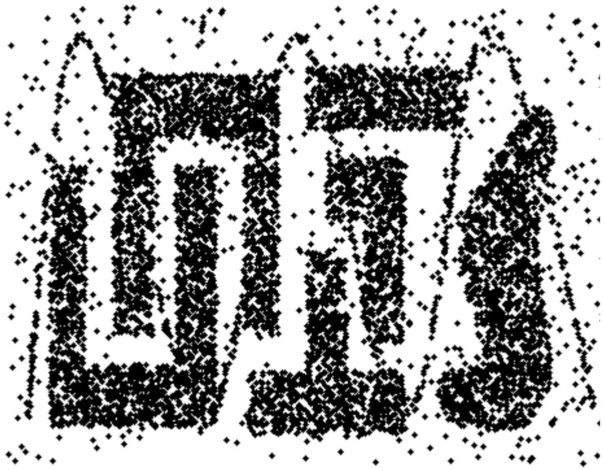
- Sampling is the main technique employed for data selection.
  - It is often used for both the preliminary investigation of the data and the final data analysis.

- Statisticians sample because obtaining the entire set of data of interest is too expensive or time consuming.

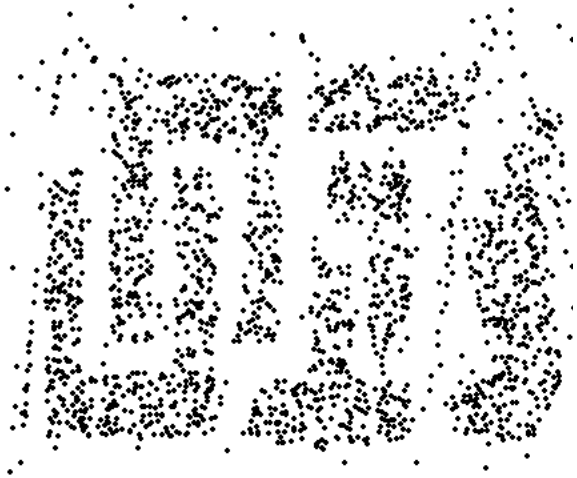
Sampling

- The key principle for effective sampling is the following:
  - Using a sample will work almost as well as using the entire data sets, if the sample is representative
  - A sample is representative if it has approximately the same property (of interest) as the original set of data

Sample Size



8000 points



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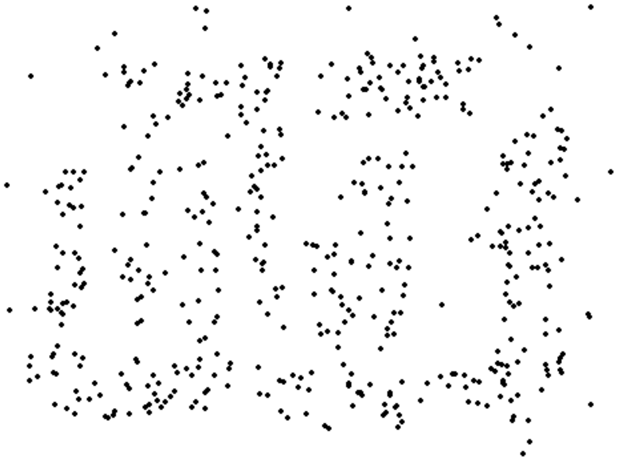
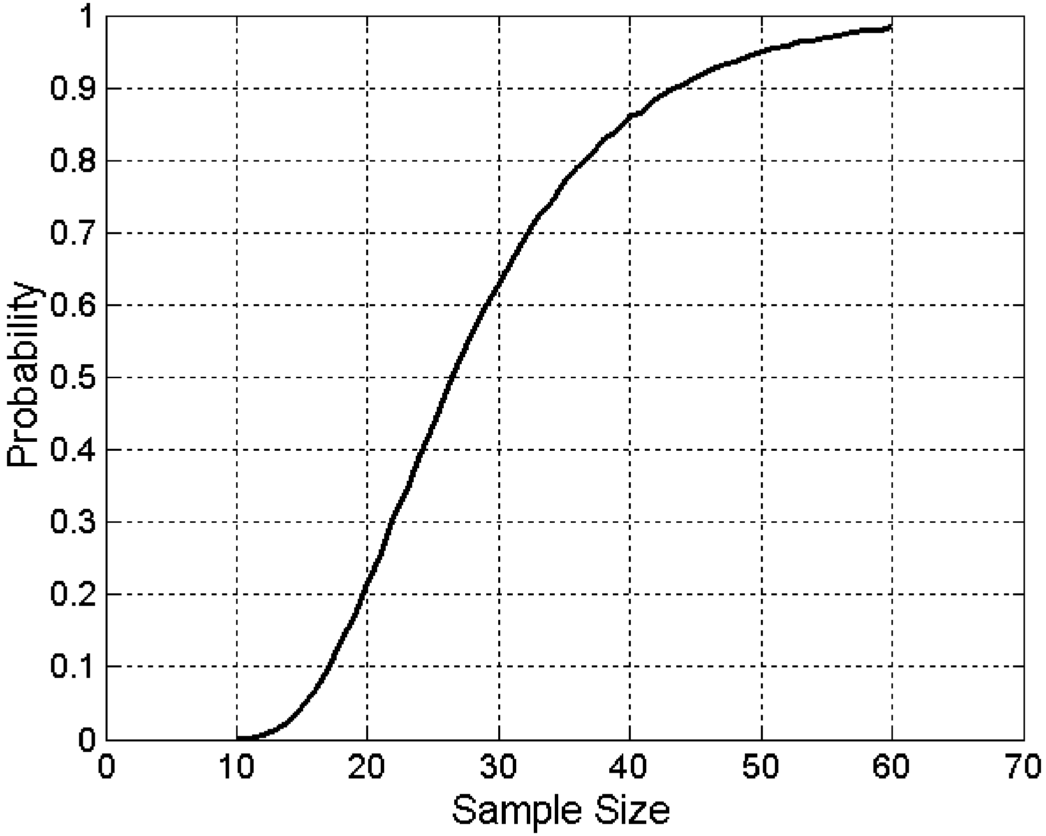


500 Points

Sample Size

- E.g., What sample size is necessary to get at least one object from each of 10 equal-sized groups?



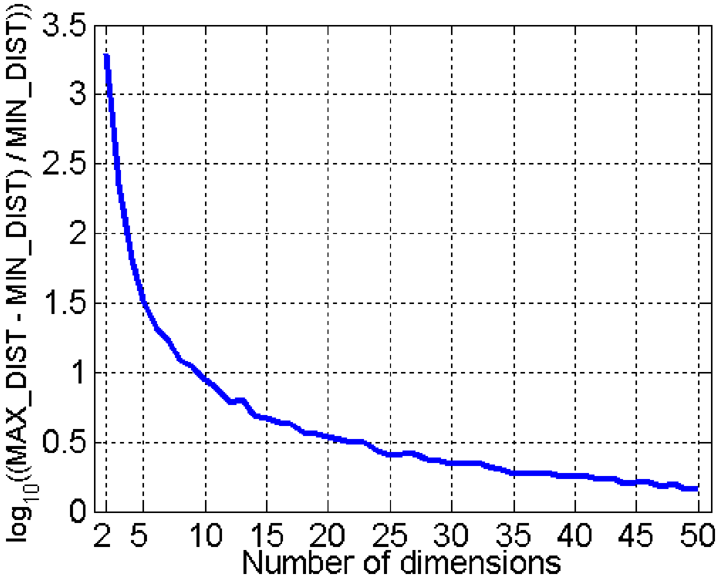
Curse of Dimensionality

- When dimensionality increases, data becomes increasingly sparse in the space that it occupies

- Definitions of density and distance between points, which is critical for clustering and outlier detection, become less meaningful

- If N_1 = 100 represents a dense sample for a single input problem, then $N_{10} = 100^{10}$ is the sample size required for the same sampling density with dimension 10.

- The proportion of a hypersphere with radius *r* and dimension *d*, to that of a hyercube with sides of length *2r* and dimension *d* converges to 0 as *d* goes to infinity — nearly all of the high-dimensional space is "far away" from the center



- Randomly generate 500 points
- Compute difference between max and min distance between any pair of points

Curse of Dimensionality

- Typical text categorization problem:
  - *TREC-AP* headlines (Cohen&Singer,2000): 319,000+ documents, 67,000+ words, 3,647,000+ word 4-grams used as features.
- *How can you learn with so many features?*
  - For speed, exploit *sparse* features.
  - Use simple classifiers (linear or loglinear)

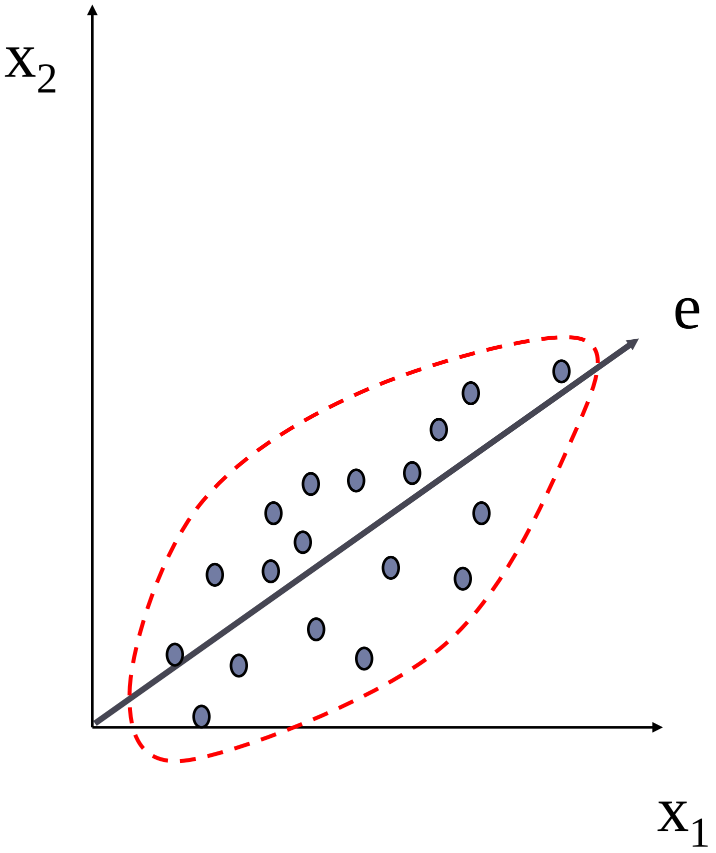
Dimensionality Reduction

- Purpose:
  - Avoid curse of dimensionality
  - Reduce amount of time and memory required by data mining algorithms
  - Allow data to be more easily visualized
  - May help to eliminate irrelevant features or reduce noise

- Techniques
  - Principal Components Analysis (PCA)
  - Singular Value Decomposition
  - Others: supervised and non-linear techniques

Dimensionality Reduction: PCA

- Goal is to find a projection that captures the largest amount of variation in data



Dimensionality Reduction: PCA

Feature Subset Selection

- Another way to reduce dimensionality of data
- Redundant features
  - Duplicate much or all of the information contained in one or more other attributes
  - Example: purchase price of a product and the amount of sales tax paid
- Irrelevant features
  - Contain no information that is useful for the data mining task at hand
  - Example: students' ID is often irrelevant to the task of predicting students' GPA
- Many techniques developed, especially for classification

Feature Creation

- Create new attributes that can capture the important information in a data set much more efficiently than the original attributes

- Three general methodologies:
  - Feature extraction

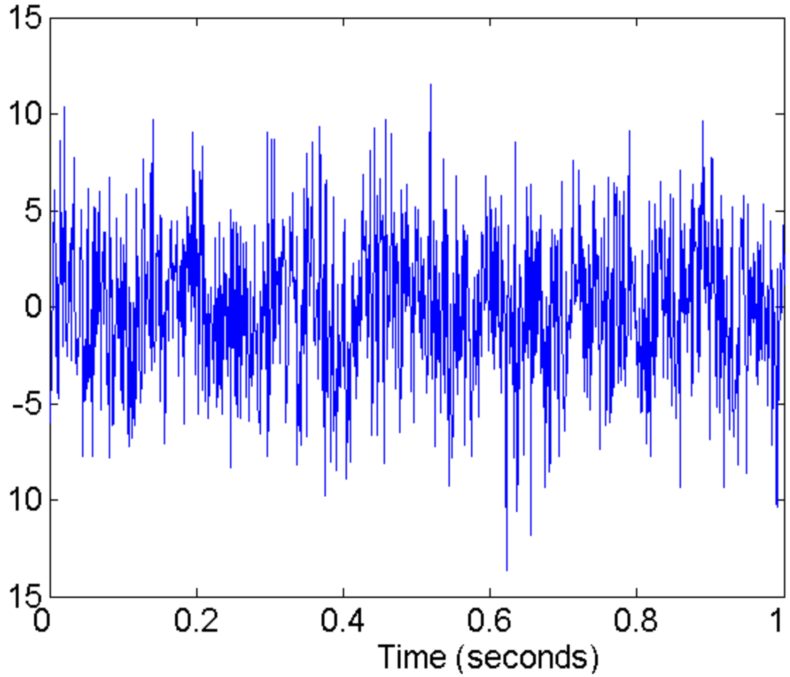
    Example: extracting edges from images
  - Feature construction

    Example: dividing mass by volume to get density
  - Mapping data to new space

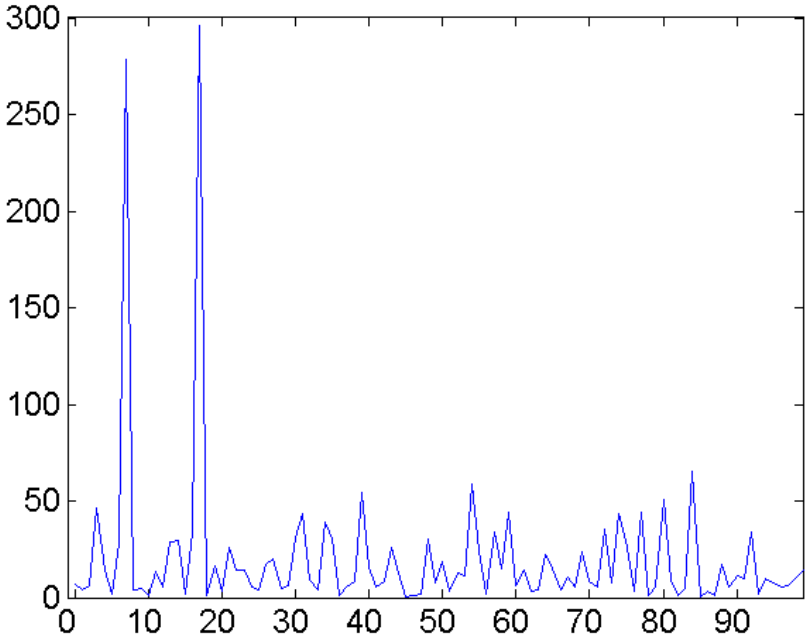
    Example: Fourier and wavelet analysis

Mapping Data to a New Space

- Fourier and wavelet transform



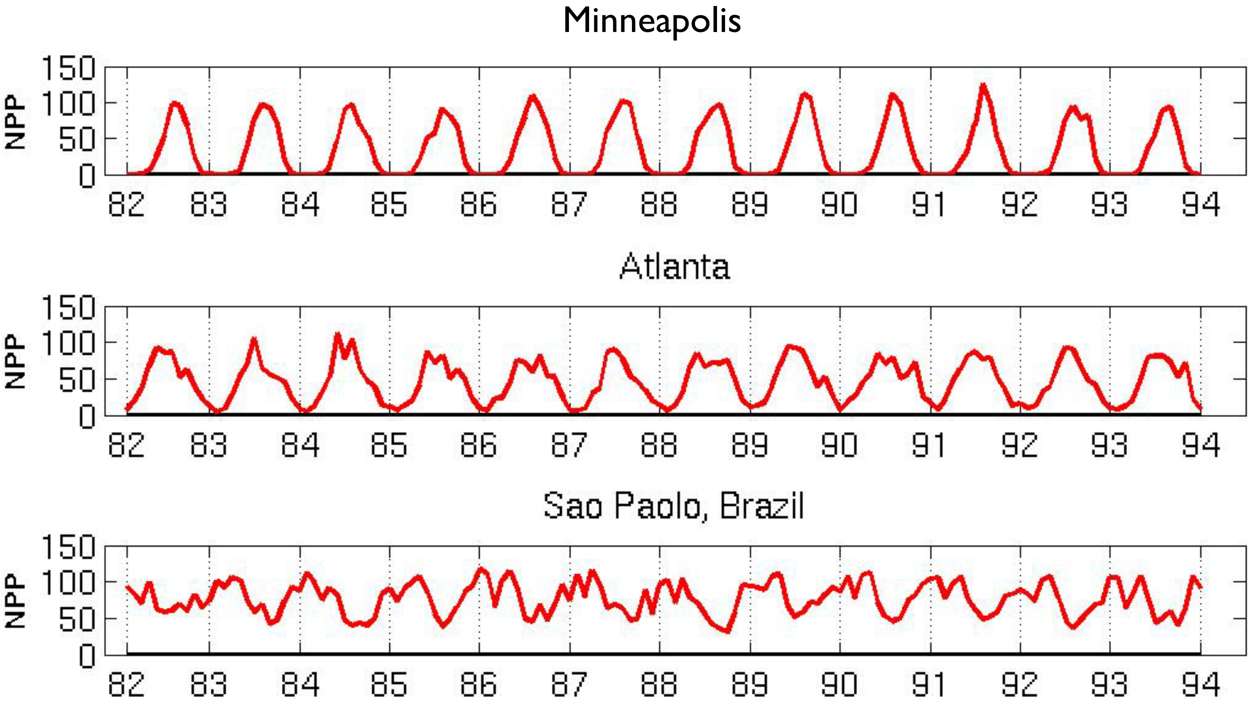
Two Sine Waves + Noise



Frequency

Attribute Transformation

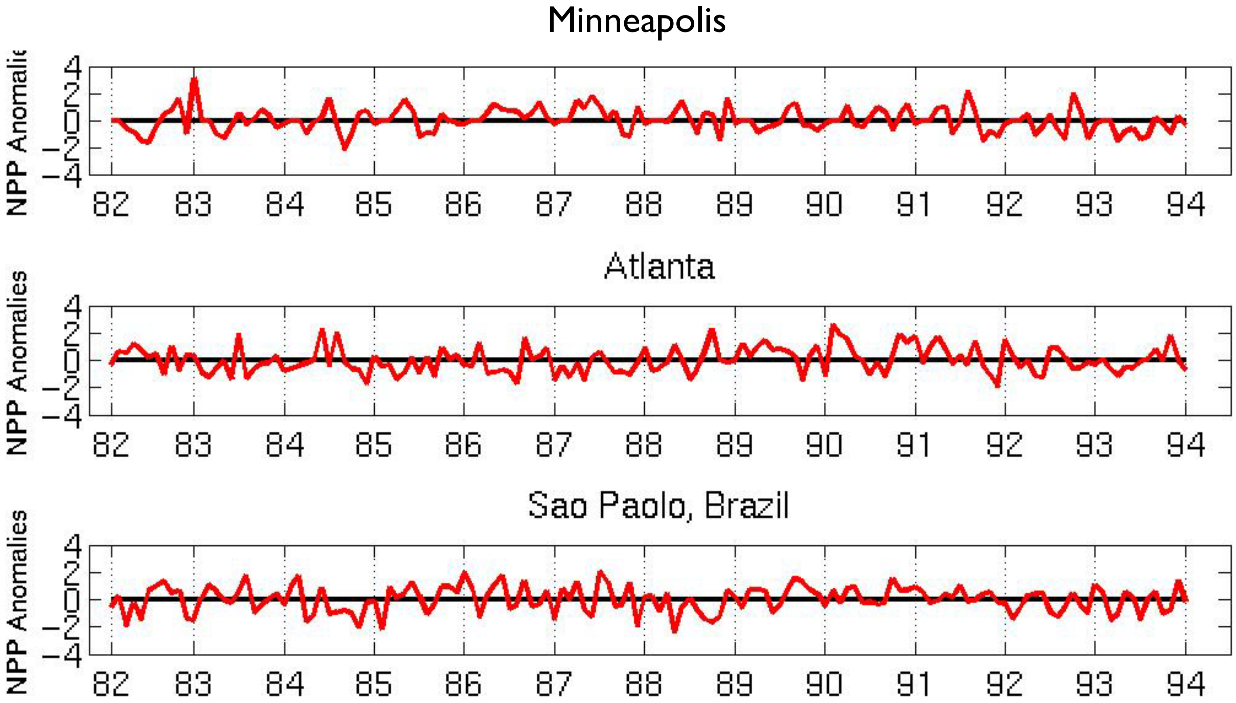
- An attribute transform is a function that maps the entire set of values of a given attribute to a new set of replacement values such that each old value can be identified with one of the new values
  - Simple functions: x^k, $\log(x)$, e^x, $|x|$
  - Normalization
    - Refers to various techniques to adjust to differences among attributes in terms of frequency of occurrence, mean, variance, magnitude
  - In statistics, standardization refers to subtracting off the means and dividing by the standard deviation



Net Primary Production (NPP) is a measure of plant growth used by ecosystem scientists.

Correlations between time series

	Minneapolis	Atlanta	Sao Paolo
Minneapolis	1.0000	0.7591	-0.7581
Atlanta	0.7591	1.0000	-0.5739
Sao Paolo	-0.7581	-0.5739	1.0000



Minneapolis

Atlanta

Sao Paolo, Brazil

Normalized using monthly Z Score:

Subtract off monthly mean and divide by monthly standard deviation

Correlations between time series

	Minneapolis	Atlanta	Sao Paolo
Minneapolis	1.0000	0.0492	0.0906
Atlanta	0.0492	1.0000	-0.0154
Sao Paolo	0.0906	-0.0154	1.0000

Summary

- Attributes and Objects
  - Attribute types: nominal / ordinal / interval / ratio; discrete / continuous
- Types of Data
  - Record, graph and network, ordered, spatial…
- Data Quality
  - Noise, outliers, missing values, duplicate data
- Data Preprocessing
  - Sampling, dimensionality reduction, feature selection…
  - Curse of dimensionality