CSE4334/5334 Data Mining

4 Data and Data Preprocessing

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What is Data?

Collection of data objects and their attributes

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**

Attribute Values

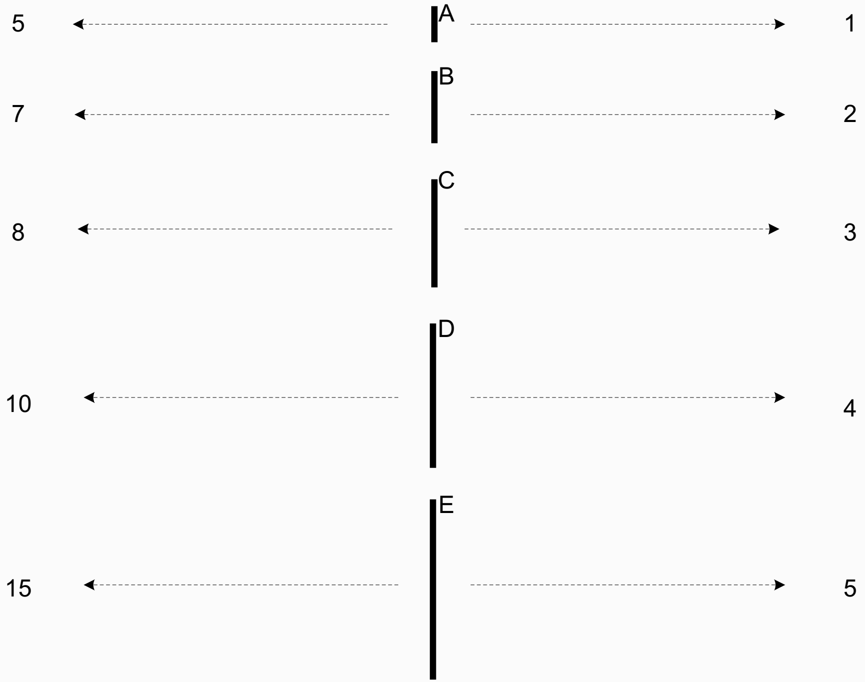
Attribute values are numbers or symbols assigned to an attribute

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
        - ID has no limit but age has a maximum and minimum value

Measurement of Length

The way you measure an attribute may not match the attributes properties.



Types of Attributes

By measure scale

- Categorical (Qualitative) Attribute
  - Nominal
  - Ordinal
- Numeric (Quantitative) Attribute
  - Interval
  - Ratio

By number of values

- Discrete Attribute
- Continuous Attribute

Types of Attributes

There are different types of attributes

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

Properties of Attribute Values

The type of an attribute depends on which of the following properties it possesses:

- Distinctness: = ≠
- Order: < >
- Addition: + -
- Multiplication: * /

- Nominal attribute: distinctness
- Ordinal attribute: distinctness & order
- Interval attribute: distinctness, order & addition
- Ratio attribute: all 4 properties

Attribute Type	Description	Examples	Operations
Nominal	The values of a nominal attribute are just different names, i.e., nominal attributes provide only enough information to distinguish one object from another. (=, ≠)	zip codes, employee ID numbers, eye color, sex: {*male, female*}	mode, entropy, contingency correlation, χ^2 test
Ordinal	The values of an ordinal attribute provide enough information to order objects. (<, >)	hardness of minerals, {*good, better, best*}, grades, street numbers	median, percentiles, rank correlation, run tests, sign tests
Interval	For interval attributes, the differences between values are meaningful, i.e., a unit of measurement exists. (+, -)	calendar dates, temperature in Celsius or Fahrenheit	mean, standard deviation, Pearson's correlation, t and F tests
Ratio	For ratio variables, both differences and ratios are meaningful. (*, /)	temperature in Kelvin, monetary quantities, counts, age, mass, length, electrical current	geometric mean, harmonic mean, percent variation

Attribute Level	Transformation	Comments
Nominal	Any permutation of values	If all employee ID numbers were reassigned, would it make any difference?
Ordinal	An order preserving change of values, i.e., $new\_value = f(old\_value)$ where f is a monotonic function.	An attribute encompassing the notion of good, better best can be represented equally well by the values {1, 2, 3} or by { 0.5, 1, 10}.
Interval	$new\_value =a * old\_value + b$ where a and b are constants	Thus, the Fahrenheit and Celsius temperature scales differ in terms of where their zero value is and the size of a unit (degree).
Ratio	$new\_value = a * old\_value$	Length can be measured in meters or feet.

Discrete and Continuous Attributes

Discrete Attribute

- Has only a finite or countably infinite set of values
- Examples: 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

Continuous Attribute

- Has real numbers as attribute values
- Examples: 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.

Types of data sets

Record

- Data Matrix
- Document Data
- Transaction Data

Graph

- World Wide Web
- Molecular Structures

Ordered

- Spatial Data
- Temporal Data
- Sequential Data
- Genetic Sequence Data

Important Characteristics of Structured Data

Dimensionality

- Curse of Dimensionality

Sparsity

- Only presence counts

Resolution

- Patterns depend on the scale

Record Data

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

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Data Matrix

If data objects have the same fixed set of numeric attributes, then the data objects can be thought of as points in a multi-dimensional space, where each dimension represents a distinct attribute

Such data set can be represented by an m by n matrix, where there are m rows, one for each object, and n columns, one for each attribute

Projection of x Load	Projection of y load	Distance	Load	Thickness
10.23	5.27	15.22	2.7	1.2
12.65	6.25	16.22	2.2	1.1

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

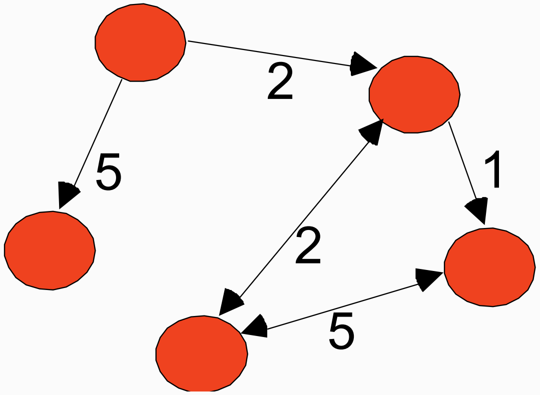
A special type of record data, where

- 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 and HTML Links



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Data Mining </a>
<li>
<a href="papers/papers.html#aaaa">
Graph Partitioning </a>
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<a href="papers/papers.html#aaaa">
Parallel Solution of Sparse Linear System of Equations </a>
<li>
<a href="papers/papers.html#ffff">
N-Body Computation and Dense Linear System Solvers
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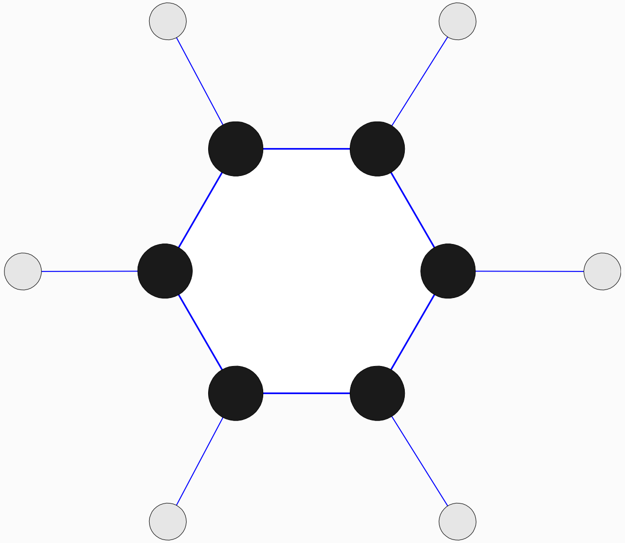
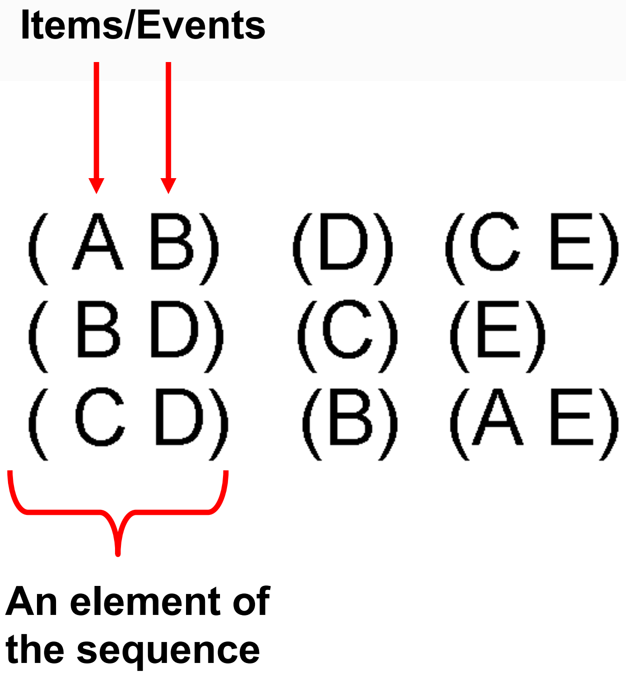
Chemical Data

Benzene Molecule: C_6H_6



Ordered Data

Sequences of transactions



Items/Events

(A B) (D) (C E)
(B D) (C) (E)
(C D) (B) (A E)

An element of the sequence

Ordered Data

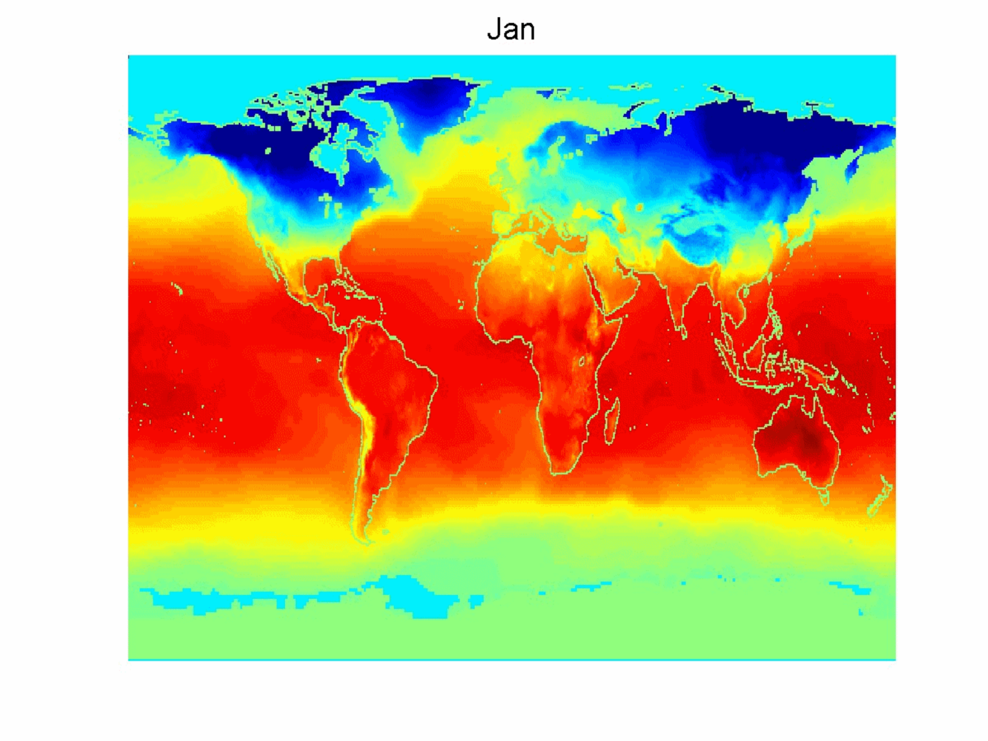
Genomic sequence data

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

Ordered Data

Spatio-Temporal Data

Average Monthly Temperature of land and ocean



Data Quality

What kinds of data quality problems?

How can we detect problems with the data?

What can we do about these problems?

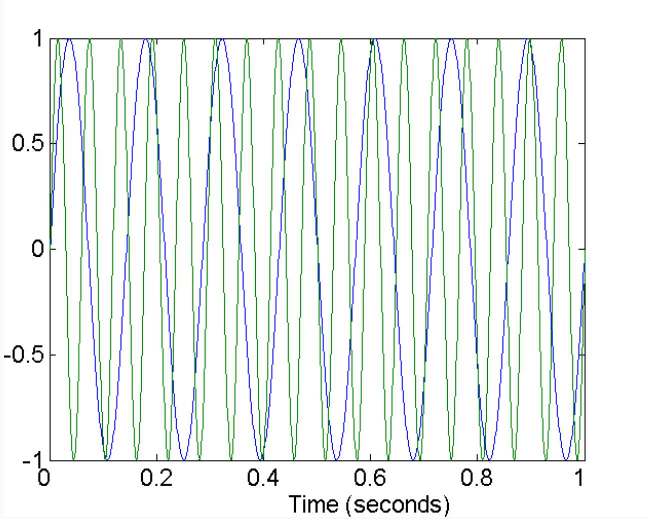
Examples of data quality problems:

- Noise and outliers
- missing values
- duplicate data

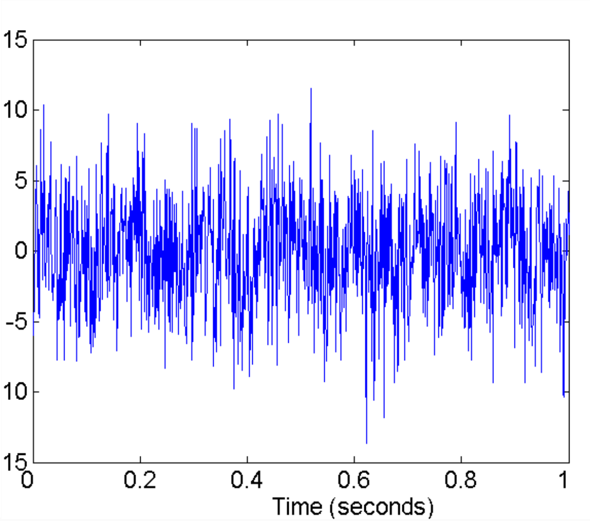
Noise

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



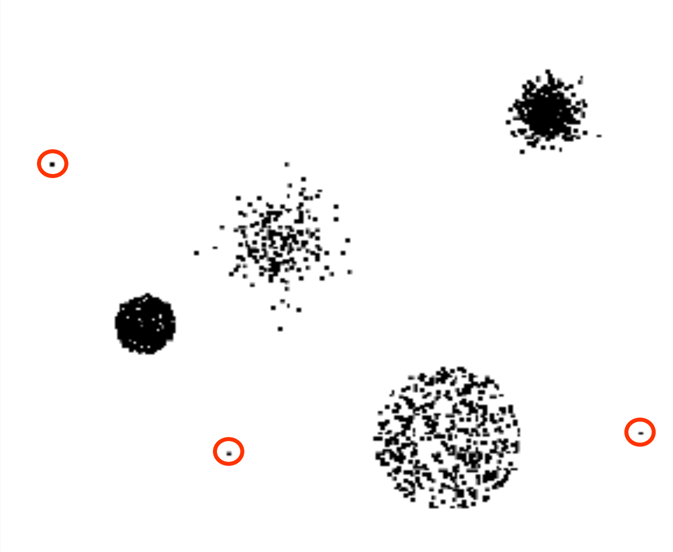
Two Sine Waves



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



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
- Ignore the Missing Value During Analysis
- Replace with all possible values (weighted by their probabilities)

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

Aggregation

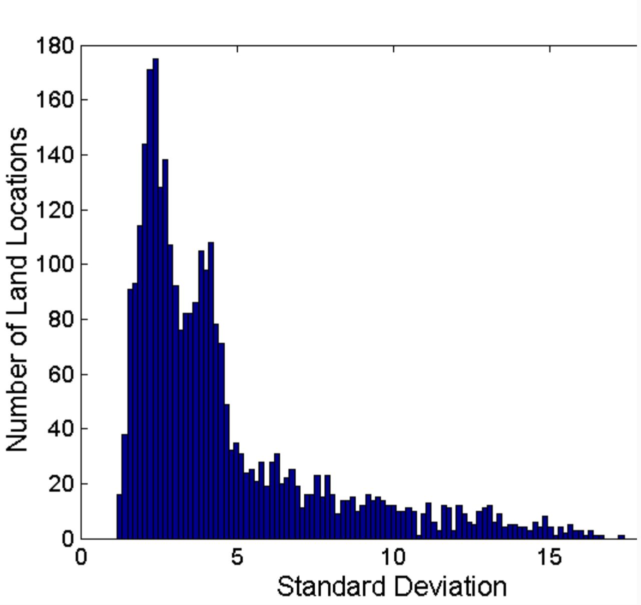
Combining two or more attributes (or objects) into a single attribute (or object)

Purpose

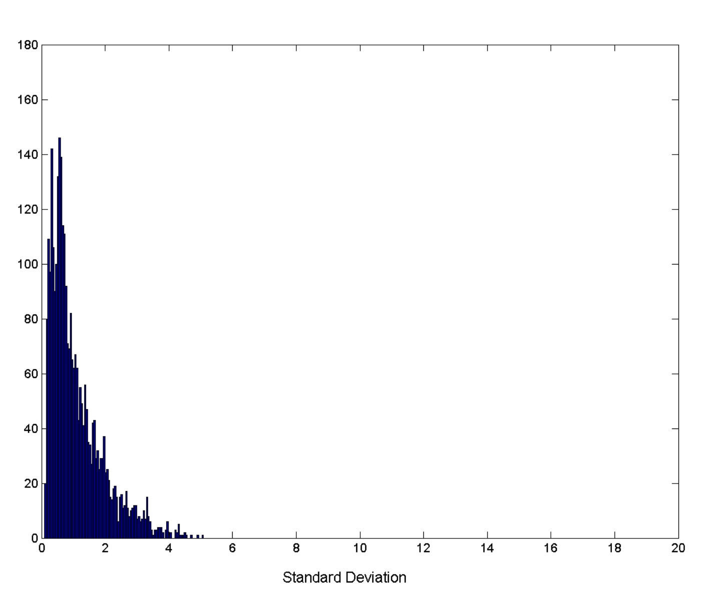
- Data reduction
  - Reduce the number of attributes or objects
- Change of scale
  - Cities aggregated into regions, states, countries, etc
- More “stable” data
  - Aggregated data tends to have less variability

Aggregation

Variation of Precipitation in Australia



Standard Deviation of Average Monthly Precipitation



Standard Deviation of Average Yearly Precipitation

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 is used in data mining because processing 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

Types of Sampling

Simple Random Sampling

- There is an equal probability of selecting any particular item

Sampling without replacement

- As each item is selected, it is removed from the population

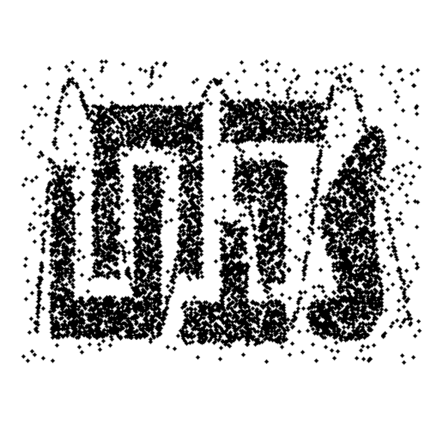
Sampling with replacement

- Objects are not removed from the population as they are selected for the sample.
  - In sampling with replacement, the same object can be picked up more than once

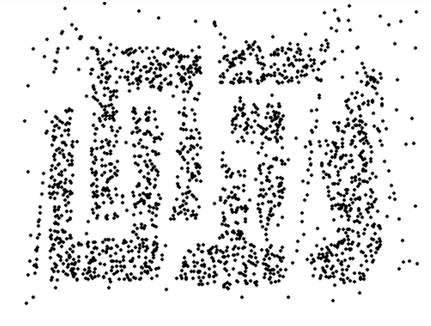
Stratified sampling

- Split the data into several partitions; then draw random samples from each partition

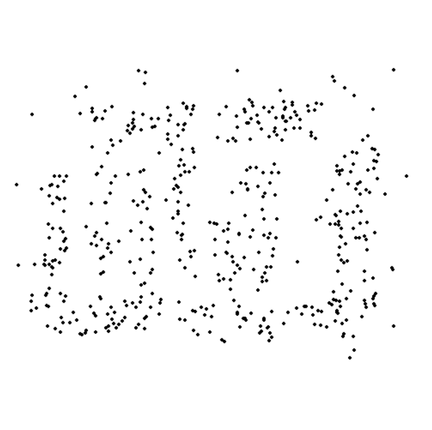
Sample Size



8000 points



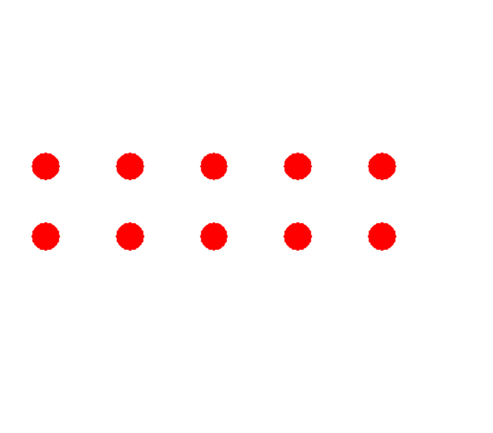
2000 Points

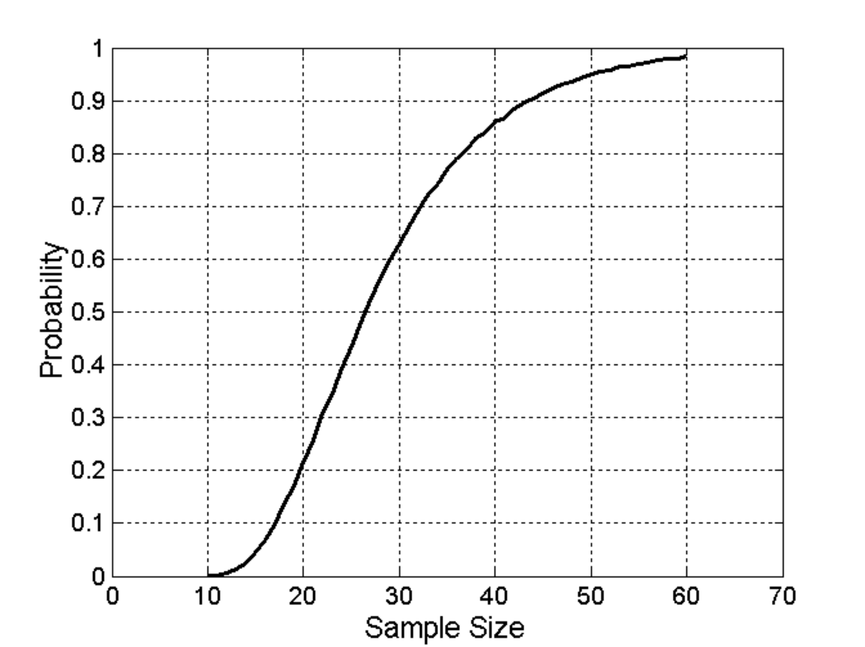


500 Points

Sample Size

What sample size is necessary to get at least one object from each of 10 groups.

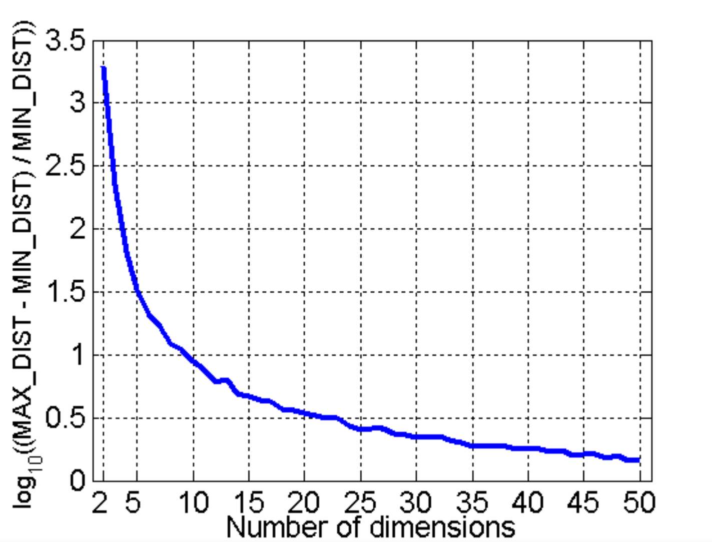




Curse of Dimensionality

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



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

Dimensionality Reduction

Purpose:

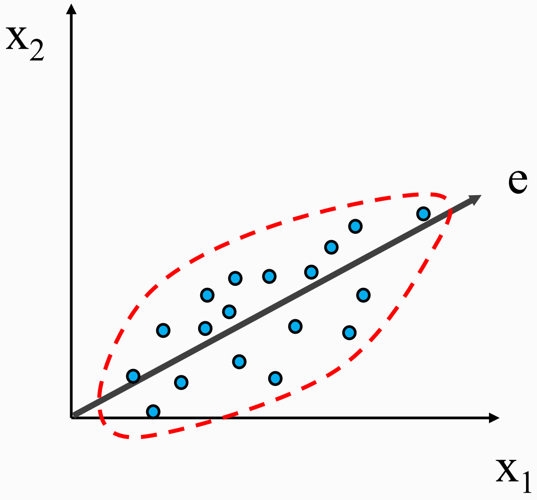
- Avoid curse of dimensionality
- Reduce amount of time and memory required by data mining algorithms
- Allow data to be more easily visualized
- May help to eliminate irrelevant features or reduce noise

Techniques

- Principle Component Analysis
- Singular Value Decomposition
- Others: supervised and non-linear techniques

Dimensionality Reduction: PCA

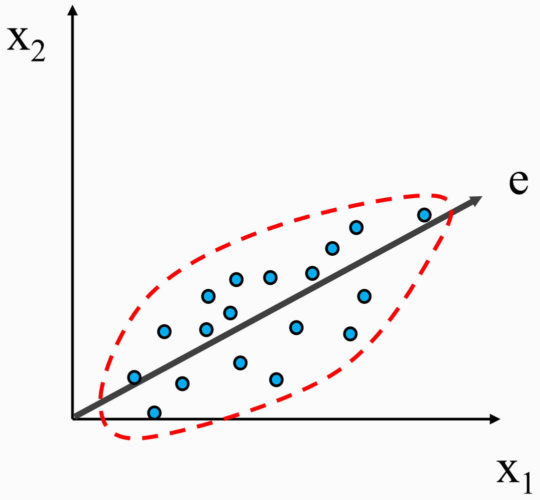
Goal is to find a projection that captures the largest amount of variation in data



Dimensionality Reduction: PCA

Find the eigenvectors of the covariance matrix

The eigenvectors define the new space



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

Feature Subset Selection

Techniques:

- Brute-force approach:
  - Try all possible feature subsets as input to data mining algorithm
- Embedded approaches:
  - Feature selection occurs naturally as part of the data mining algorithm
- Filter approaches:
  - Features are selected before data mining algorithm is run
- Wrapper approaches:
  - Use the data mining algorithm as a black box to find best subset of attributes

Feature Creation

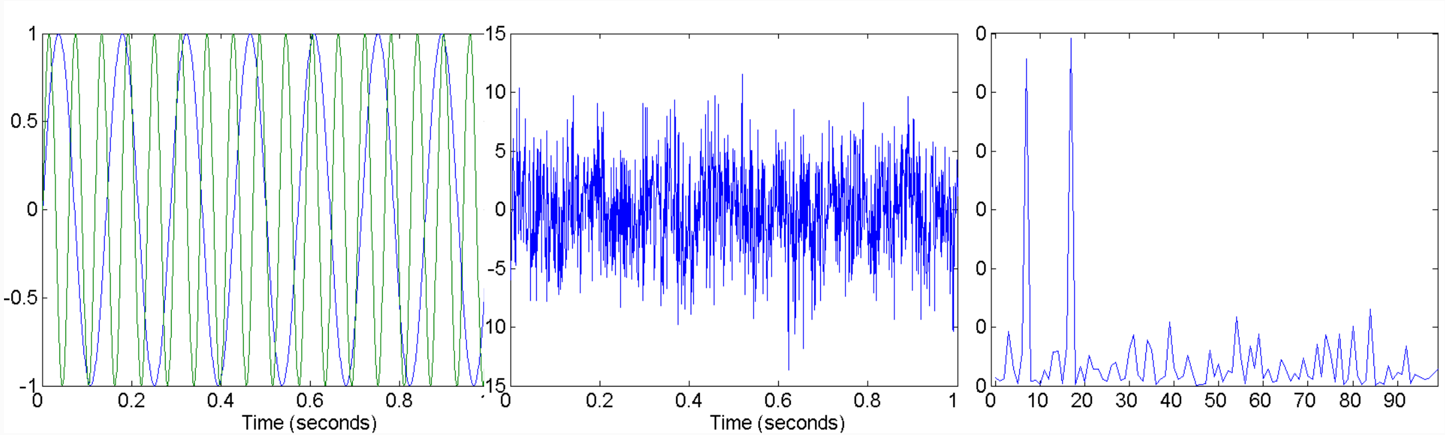
Create new attributes that can capture the important information in a data set much more efficiently than the original attributes

Three general methodologies:

- Feature Extraction
  - domain-specific
- Mapping Data to New Space
- Feature Construction
  - combining features

Mapping Data to a New Space

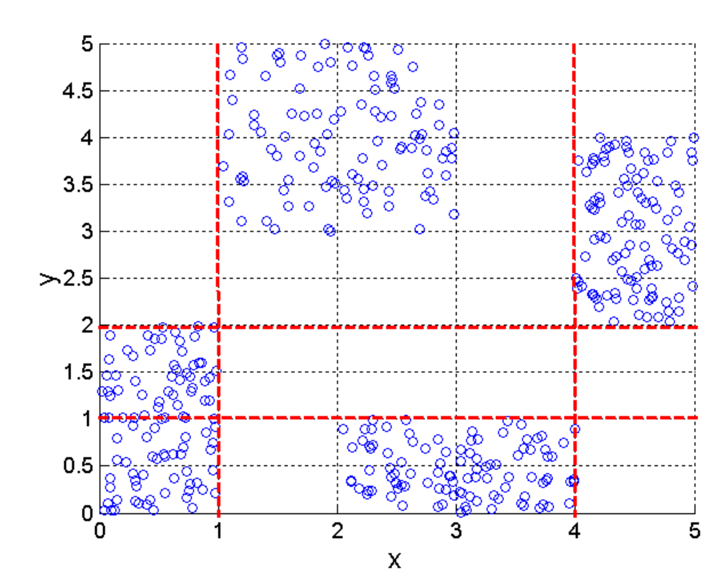
- Fourier transform
- Wavelet transform



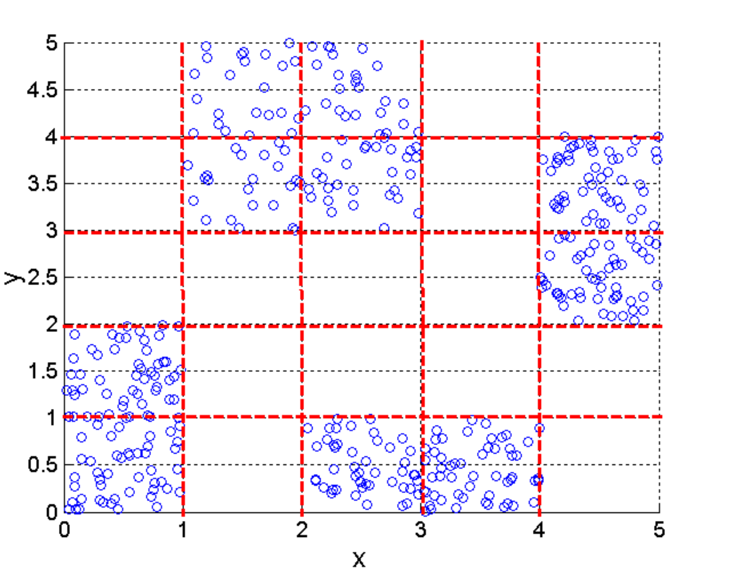
Two Sine Waves **Two Sine Waves + Noise** **Frequency**

Discretization Using Class Labels

Entropy based approach

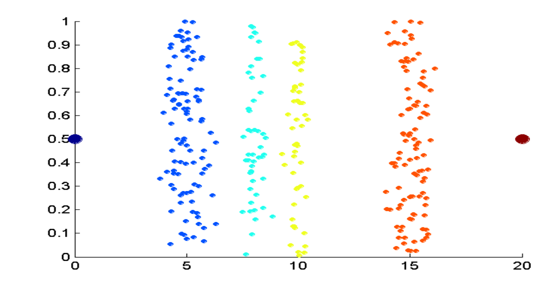


3 categories for both x and y



5 categories for both x and y

Discretization Without Using Class Labels



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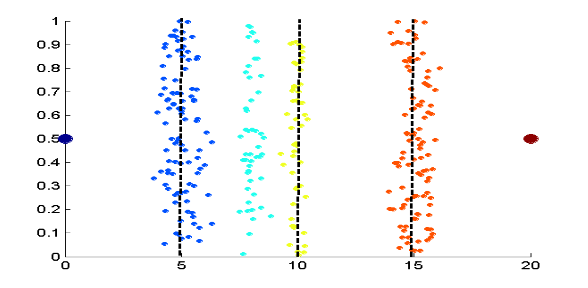
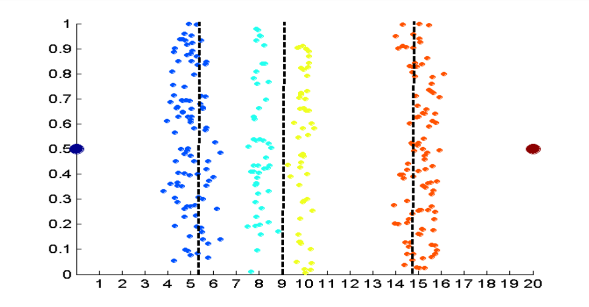
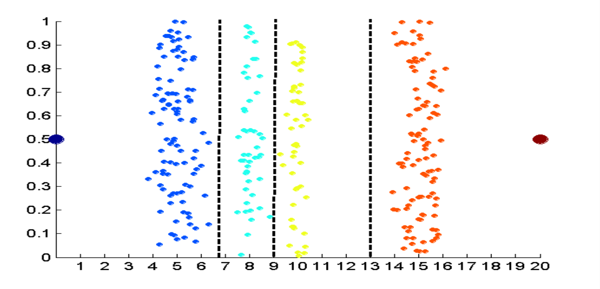


Equal interval width



Equal frequency

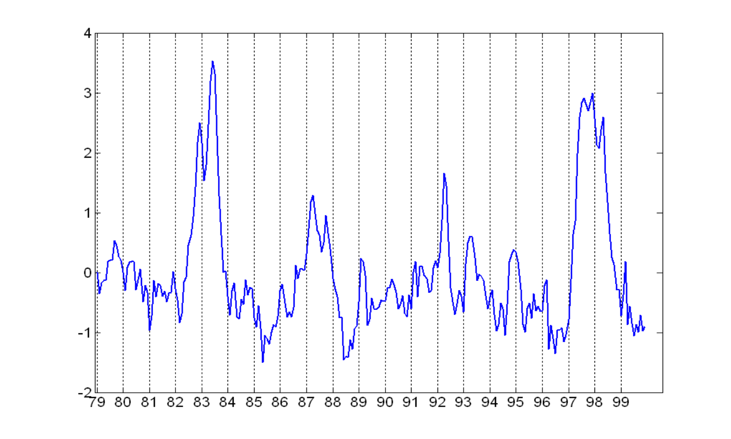


K-means

Attribute Transformation

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|
- Standardization and Normalization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