

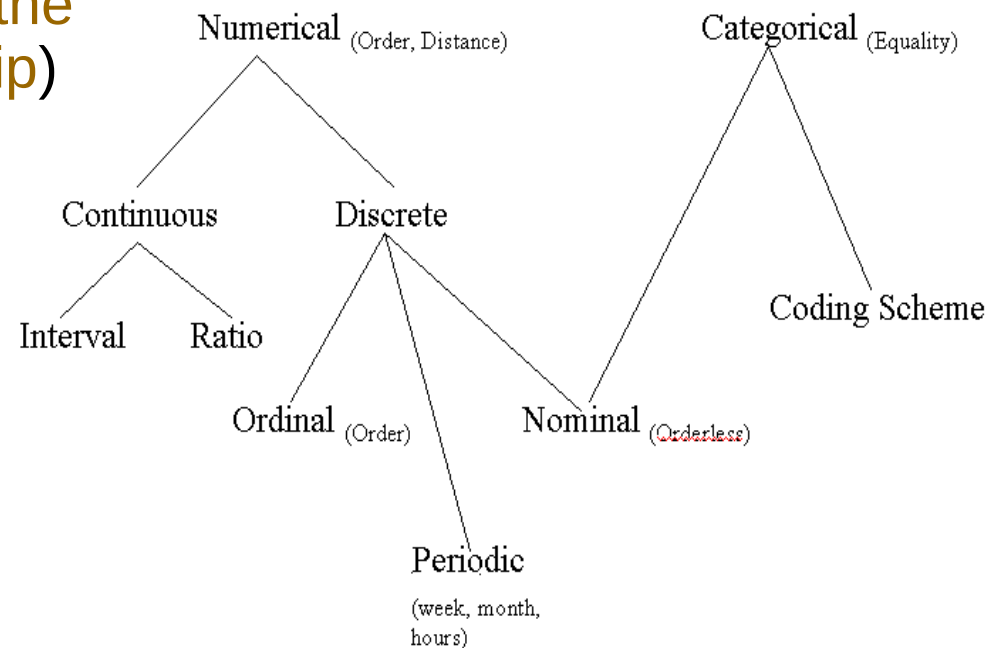
Chapter 1

Data Preprocessing

Data Types and Forms

- Attribute-value data:
- Data types
 - numeric, categorical (see the hierarchy for its relationship)
 - static, dynamic (temporal)
- Other kinds of data
 - distributed data
 - text, Web, meta data
 - images, audio/video

A1	A2	...	An	C



Chapter 2: Data Preprocessing

- Why preprocess the data?
- Data cleaning
- Data integration and transformation
- Data reduction
- Discretization
- Summary

Why Data Preprocessing?

- Data in the real world is dirty
 - **incomplete**: missing attribute values, lack of certain attributes of interest, or containing only aggregate data
 - e.g., occupation=""
 - **noisy**: containing errors or outliers
 - e.g., Salary="-10"
 - **inconsistent**: containing discrepancies in codes or names
 - e.g., Age="42" Birthday="03/07/1997"
 - e.g., Was rating "1,2,3", now rating "A, B, C"
 - e.g., discrepancy between duplicate records

Why Is Data Preprocessing Important?

- No quality data, no quality mining results!
 - Quality decisions must be based on quality data
 - e.g., duplicate or missing data may cause incorrect or even misleading statistics.
- Data preparation, cleaning, and transformation comprises the majority of the work in a data mining application (90%).

Multi-Dimensional Measure of Data Quality

- A well-accepted multi-dimensional view:
 - ❑ Accuracy
 - ❑ Completeness
 - ❑ Consistency
 - ❑ Timeliness
 - ❑ Believability
 - ❑ Value added
 - ❑ Interpretability
 - ❑ Accessibility

Major Tasks in Data Preprocessing

- Data cleaning
 - Fill in missing values, smooth noisy data, identify or remove outliers and noisy data, and resolve inconsistencies
- Data integration
 - Integration of multiple databases, or files
- Data transformation
 - Normalization and aggregation
- Data reduction
 - Obtains reduced representation in volume but produces the same or similar analytical results
- Data discretization (for numerical data)

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Data Cleaning

- Importance
 - “Data cleaning is the number one problem in data warehousing”
- Data cleaning tasks
 - Fill in missing values
 - Identify outliers and smooth out noisy data
 - Correct inconsistent data
 - Resolve redundancy caused by data integration

Missing Data

- Data is not always available
 - E.g., many tuples have no recorded values for several attributes, such as customer income in sales data
- Missing data may be due to
 - equipment malfunction
 - inconsistent with other recorded data and thus deleted
 - data not entered due to misunderstanding
 - certain data may not be considered important at the time of entry
 - not register history or changes of the data

How to Handle Missing Data?

- Ignore the tuple
- Fill in missing values manually: tedious + infeasible?
- Fill in it automatically with
 - a global constant : e.g., “unknown”, a new class?!
 - the attribute mean
 - the most probable value: inference-based such as Bayesian formula, decision tree, or EM algorithm

Noisy Data

- Noise: random error or variance in a measured variable.
- Incorrect attribute values may due to
 - faulty data collection instruments
 - data entry problems
 - data transmission problems
 - etc
- Other data problems which requires data cleaning
 - duplicate records, incomplete data, inconsistent data

How to Handle Noisy Data?

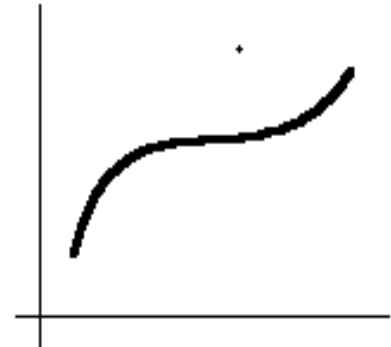
- Binning method:
 - first sort data and partition into (equi-depth) bins
 - then one can smooth by bin means, smooth by bin median, smooth by bin boundaries, etc.
- Clustering
 - detect and remove outliers
- Combined computer and human inspection
 - detect suspicious values and check by human (e.g., deal with possible outliers)

Binning Methods for Data Smoothing

- Sorted data for price (in dollars): 4, 8, 9, 15, 21, 21, 24, 25, 26, 28, 29, 34
- Partition into (equi-depth) bins:
 - Bin 1: 4, 8, 9, 15
 - Bin 2: 21, 21, 24, 25
 - Bin 3: 26, 28, 29, 34
- Smoothing by bin means:
 - Bin 1: 9, 9, 9, 9
 - Bin 2: 23, 23, 23, 23
 - Bin 3: 29, 29, 29, 29
- Smoothing by bin boundaries:
 - Bin 1: 4, 4, 4, 15
 - Bin 2: 21, 21, 25, 25
 - Bin 3: 26, 26, 26, 34

Outlier Removal

- Data points inconsistent with the majority of data
- Different outliers
 - Valid: CEO's salary,
 - Noisy: One's age = 200, widely deviated points
- Removal methods
 - Clustering
 - Curve-fitting
 - Hypothesis-testing with a given model



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Data Integration

- Data integration:
 - combines data from multiple sources
- Schema integration
 - integrate metadata from different sources
 - Entity identification problem: identify real world entities from multiple data sources, e.g., $A.cust-id \equiv B.cust-\#$
- Detecting and resolving data value conflicts
 - for the same real world entity, attribute values from different sources are different, e.g., different scales, metric vs. British units
- Removing duplicates and redundant data

Data Transformation

- Smoothing: remove noise from data
- Normalization: scaled to fall within a small, specified range
- Attribute/feature construction
 - New attributes constructed from the given ones
- Aggregation: summarization
- Generalization: concept hierarchy climbing

Data Transformation: Normalization

- min-max normalization

$$v' = \frac{v - \min_A}{\max_A - \min_A} (\text{new_max}_A - \text{new_min}_A) + \text{new_min}_A$$

- z-score normalization

$$v' = \frac{v - \text{mean}_A}{\text{stand_dev}_A}$$

- normalization by decimal scaling

$$v' = \frac{v}{10^j} \quad \text{Where } j \text{ is the smallest integer such that } \text{Max}(|v'|) < 1$$

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Data Reduction Strategies

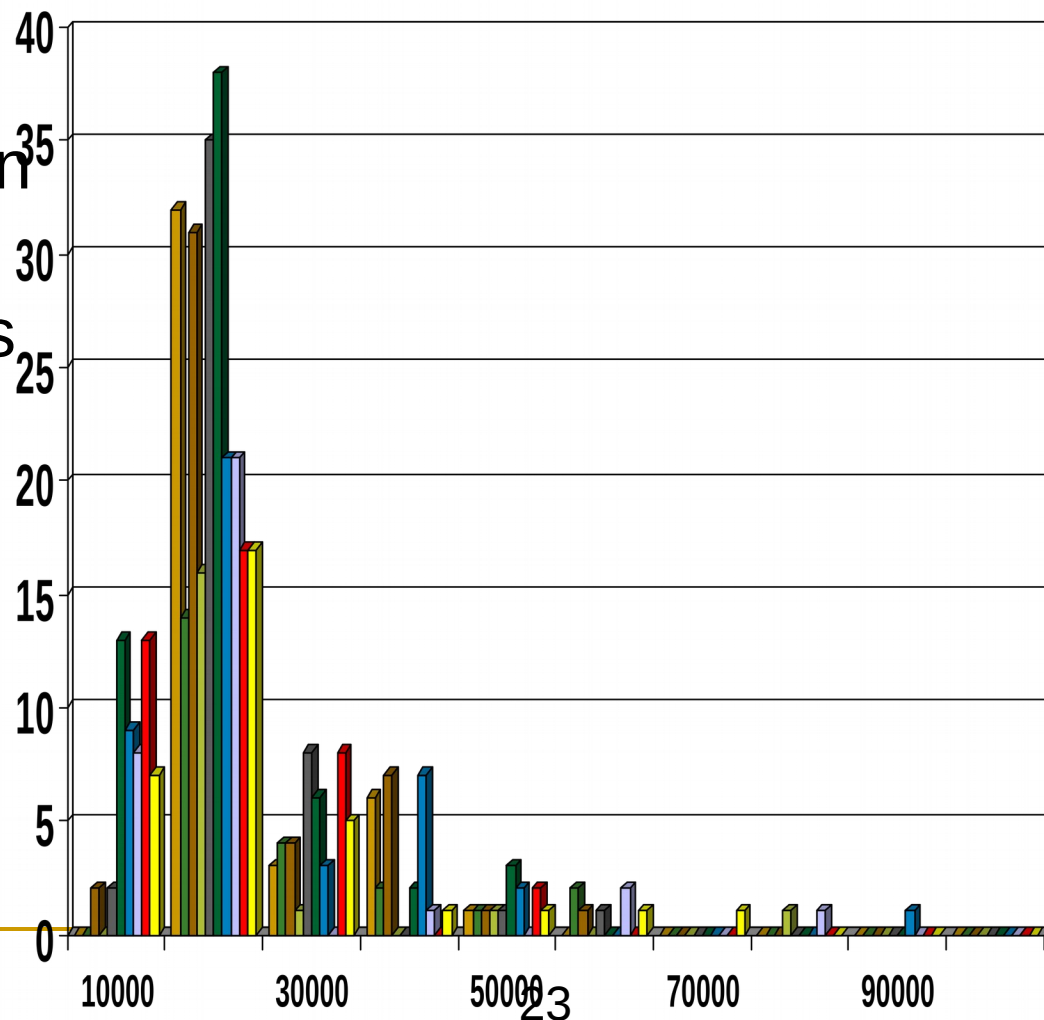
- Data is too big to work with
- Data reduction
 - Obtain a reduced representation of the data set that is much smaller in volume but yet produce the same (or almost the same) analytical results
- Data reduction strategies
 - Dimensionality reduction — remove unimportant attributes
 - Aggregation and clustering
 - Sampling

Dimensionality Reduction

- Feature selection (i.e., attribute subset selection):
 - Select a minimum set of attributes (features) that is sufficient for the data mining task.
- Heuristic methods (due to exponential # of choices):
 - step-wise forward selection
 - step-wise backward elimination
 - combining forward selection and backward elimination
 - etc

Histograms

- A popular data reduction technique
- Divide data into buckets and store average (sum) for each bucket



Clustering

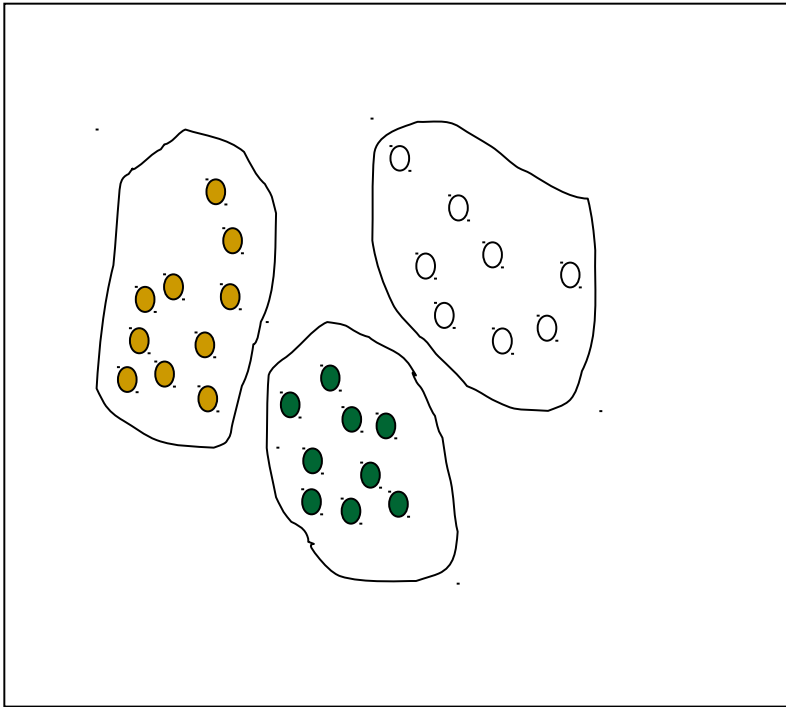
- Partition data set into clusters, and one can store cluster representation only
- Can be very effective if data is clustered but not if data is “smeared”
- There are many choices of clustering definitions and clustering algorithms. We will discuss them later.

Sampling

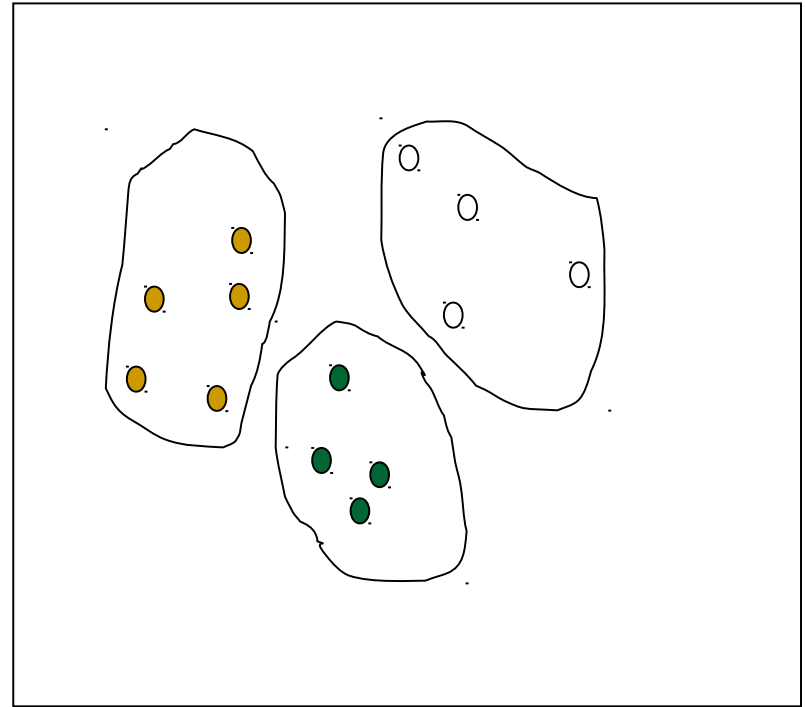
- Choose a **representative** subset of the data
 - Simple random sampling may have poor performance in the presence of skew.
- Develop adaptive sampling methods
 - Stratified sampling:
 - Approximate the percentage of each class (or subpopulation of interest) in the overall database
 - Used in conjunction with skewed data

Sampling

Raw Data



Cluster/Stratified Sample



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Discretization

- Three types of attributes:
 - Nominal — values from an unordered set
 - Ordinal — values from an ordered set
 - Continuous — real numbers
- Discretization:
 - divide the range of a continuous attribute into intervals because some data mining algorithms only accept categorical attributes.
- Some techniques:
 - Binning methods – equal-width, equal-frequency
 - Entropy-based methods

Discretization and Concept Hierarchy

■ Discretization

- reduce the number of values for a given continuous attribute by dividing the range of the attribute into intervals. Interval labels can then be used to replace actual data values

■ Concept hierarchies

- reduce the data by collecting and replacing low level concepts (such as numeric values for the attribute age) by higher level concepts (such as young, middle-aged, or senior)

Binning

- Attribute values (for one attribute e.g., age):
 - 0, 4, 12, 16, 16, 18, 24, 26, 28
- Equi-width binning – for bin width of e.g., 10:
 - Bin 1: 0, 4 [-,10) bin
 - Bin 2: 12, 16, 16, 18 [10,20) bin
 - Bin 3: 24, 26, 28 [20,+) bin
 - – denote negative infinity, + positive infinity
- Equi-frequency binning – for bin density of e.g., 3:
 - Bin 1: 0, 4, 12 [-, 14) bin
 - Bin 2: 16, 16, 18 [14, 21) bin
 - Bin 3: 24, 26, 28 [21,+] bin

Entropy-based (1)

- Given attribute-value/class pairs:
 - (0,P), (4,P), (12,P), (16,N), (16,N), (18,P), (24,N), (26,N), (28,N)
- Entropy-based binning via binarization:
 - Intuitively, find best split so that the bins are as pure as possible
 - Formally characterized by maximal information gain.
- Let S denote the above 9 pairs, $p=4/9$ be fraction of P pairs, and $n=5/9$ be fraction of N pairs.
- $\text{Entropy}(S) = -p \log p - n \log n$.
 - Smaller entropy – set is relatively pure; smallest is 0.
 - Large entropy – set is mixed. Largest is 1.

Entropy-based (2)

- Let v be a possible split. Then S is divided into two sets:
 - $S1$: value $\leq v$ and $S2$: value $> v$
- Information of the split:
 - $I(S1, S2) = (|S1|/|S|) \text{Entropy}(S1) + (|S2|/|S|) \text{Entropy}(S2)$
- Information gain of the split:
 - $\text{Gain}(v, S) = \text{Entropy}(S) - I(S1, S2)$
- **Goal:** split with maximal information gain.
- Possible splits: mid points b/w any two consecutive values.
- For $v=14$, $I(S1, S2) = 0 + 6/9 * \text{Entropy}(S2) = 6/9 * 0.65 = 0.433$
 - $\text{Gain}(14, S) = \text{Entropy}(S) - 0.433$
 - maximum *Gain* means minimum *I*.
- The best split is found after examining all possible splits.

Summary

- Data preparation is a big issue for data mining
- Data preparation includes
 - Data cleaning and data integration
 - Data reduction and feature selection
 - Discretization
- Many methods have been proposed but still an active area of research