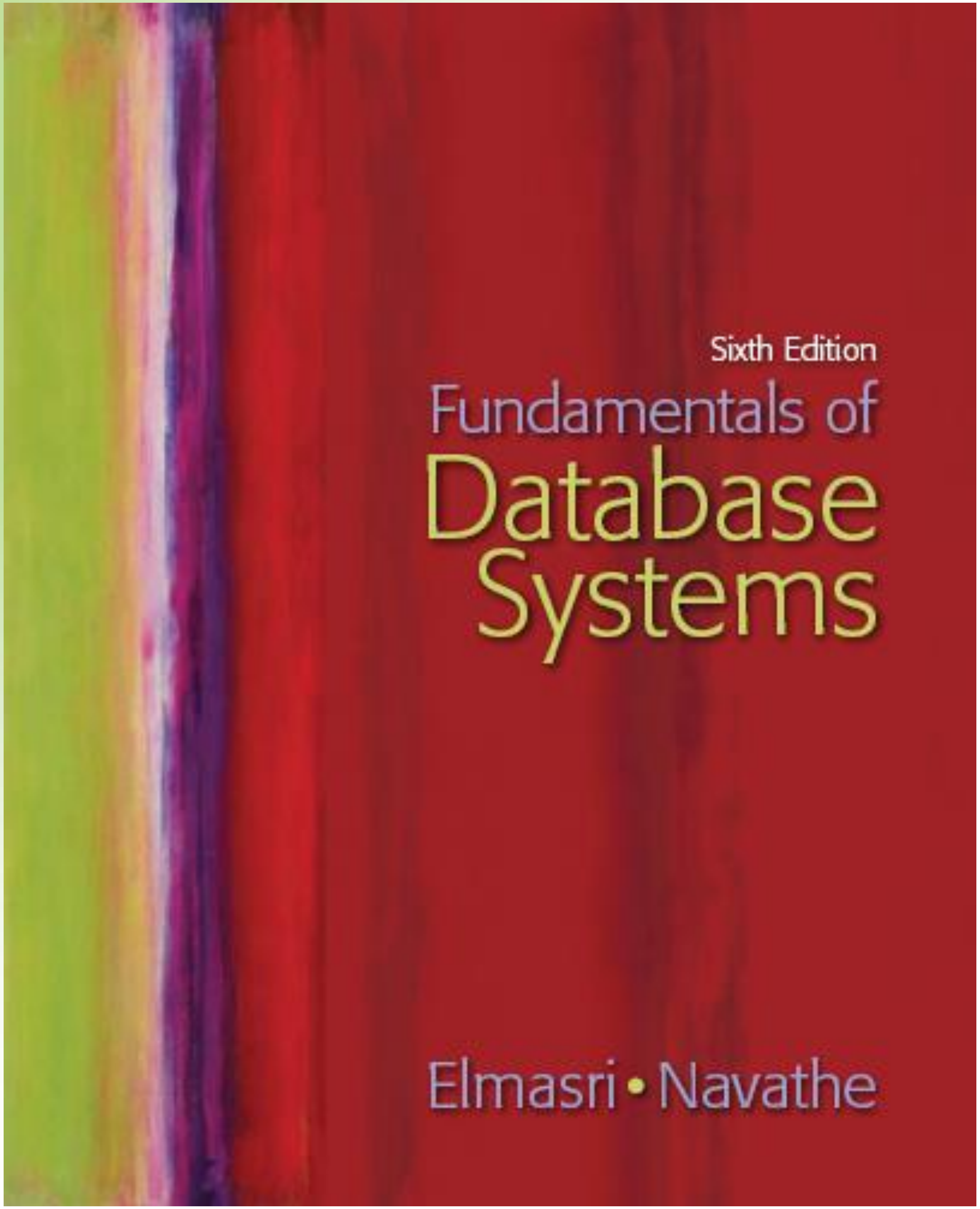
Chapter 28

Data Mining Concepts



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Definitions of Data Mining

- The discovery of new information in terms of patterns or rules from vast amounts of data.
- The process of finding interesting structure in data.
- The process of employing one or more computer learning techniques to automatically analyze and extract knowledge from data.

Data Warehousing

- The data warehouse is a historical database designed for decision support.
- Data mining can be applied to the data in a warehouse to help with certain types of decisions.
- Proper construction of a data warehouse is fundamental to the successful use of data mining.

Knowledge Discovery in Databases (KDD)

- Data mining is actually one step of a larger process known as **knowledge discovery in databases** (KDD).
- The KDD process model comprises six phases
  - Data selection
  - Data cleansing
  - Enrichment
  - Data transformation or encoding
  - Data mining
  - Reporting and displaying discovered knowledge

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Goals of Data Mining and Knowledge Discovery (PICO)

- **Prediction**:
  - Determine how certain attributes will behave in the future.
- **Identification**:
  - Identify the existence of an item, event, or activity.
- **Classification**:
  - Partition data into classes or categories.
- **Optimization**:
  - Optimize the use of limited resources.

Types of Discovered Knowledge

- Association Rules
- Classification Hierarchies
- Sequential Patterns
- Patterns Within Time Series
- Clustering

Association Rules

- Association rules are frequently used to generate rules from **market-basket data**.
  - A market basket corresponds to the sets of items a consumer purchases during one visit to a supermarket.
- The set of items purchased by customers is known as an **itemset**.
- An **association rule** is of the form X=>Y, where X ={x_1, x_2, …., x_n }, and Y = {y_1,y_2, …., y_n} are sets of items, with x_i and y_i being distinct items for all i and all j.
  - For an association rule to be of interest, it must satisfy a minimum support and confidence.

Association Rules
Confidence and Support

- **Support**:
  - The minimum percentage of instances in the database that contain all items listed in a given association rule.
  - Support is the percentage of transactions that contain all of the items in the itemset, LHS U RHS.
- **Confidence**:
  - Given a rule of the form A=>B, rule confidence is the conditional probability that B is true when A is known to be true.
  - Confidence can be computed as
    - support(LHS U RHS) / support(LHS)

Generating Association Rules

- The general algorithm for generating association rules is a two-step process.
  - Generate all itemsets that have a support exceeding the given threshold. Itemsets with this property are called **large** or **frequent itemsets**.
  - Generate rules for each itemset as follows:
    - For itemset X and Y a subset of X, let Z = X – Y;
    - If support(X)/Support(Z) > minimum confidence, the rule Z=>Y is a valid rule.

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Reducing Association Rule Complexity

- Two properties are used to reduce the search space for association rule generation.
  - **Downward Closure**
    - A subset of a large itemset must also be large
  - **Anti-monotonicity**
    - A superset of a small itemset is also small. This implies that the itemset does not have sufficient support to be considered for rule generation.

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Generating Association Rules: The Apriori Algorithm

- The **Apriori algorithm** was the first algorithm used to generate association rules.
  - The Apriori algorithm uses the general algorithm for creating association rules together with downward closure and anti-monotonicity.

Generating Association Rules: The Sampling Algorithm

- The **sampling algorithm** selects samples from the database of transactions that individually fit into memory. Frequent itemsets are then formed for each sample.
  - If the frequent itemsets form a superset of the frequent itemsets for the entire database, then the real frequent itemsets can be obtained by scanning the remainder of the database.
  - In some rare cases, a second scan of the database is required to find all frequent itemsets.

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Generating Association Rules: Frequent-Pattern Tree Algorithm

- The **Frequent-Pattern Tree** Algorithm reduces the total number of candidate itemsets by producing a compressed version of the database in terms of an FP-tree.
- The FP-tree stores relevant information and allows for the efficient discovery of frequent itemsets.
- The algorithm consists of two steps:
  - Step 1 builds the FP-tree.
  - Step 2 uses the tree to find frequent itemsets.

Generating Association Rules: The Partition Algorithm

- Divide the database into non-overlapping subsets.
- Treat each subset as a separate database where each subset fits entirely into main memory.
- Apply the Apriori algorithm to each partition.
- Take the union of all frequent itemsets from each partition.
- These itemsets form the global candidate frequent itemsets for the entire database.
- Verify the global set of itemsets by having their actual support measured for the entire database.

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Complications seen with Association Rules

- The cardinality of itemsets in most situations is extremely large.
- Association rule mining is more difficult when transactions show variability in factors such as geographic location and seasons.
- Item classifications exist along multiple dimensions.
- Data quality is variable; data may be missing, erroneous, conflicting, as well as redundant.

Classification

- **Classification** is the process of learning a model that is able to describe different classes of data.
- Learning is **supervised** as the classes to be learned are predetermined.
- Learning is accomplished by using a training set of pre-classified data.
- The model produced is usually in the form of a decision tree or a set of rules.

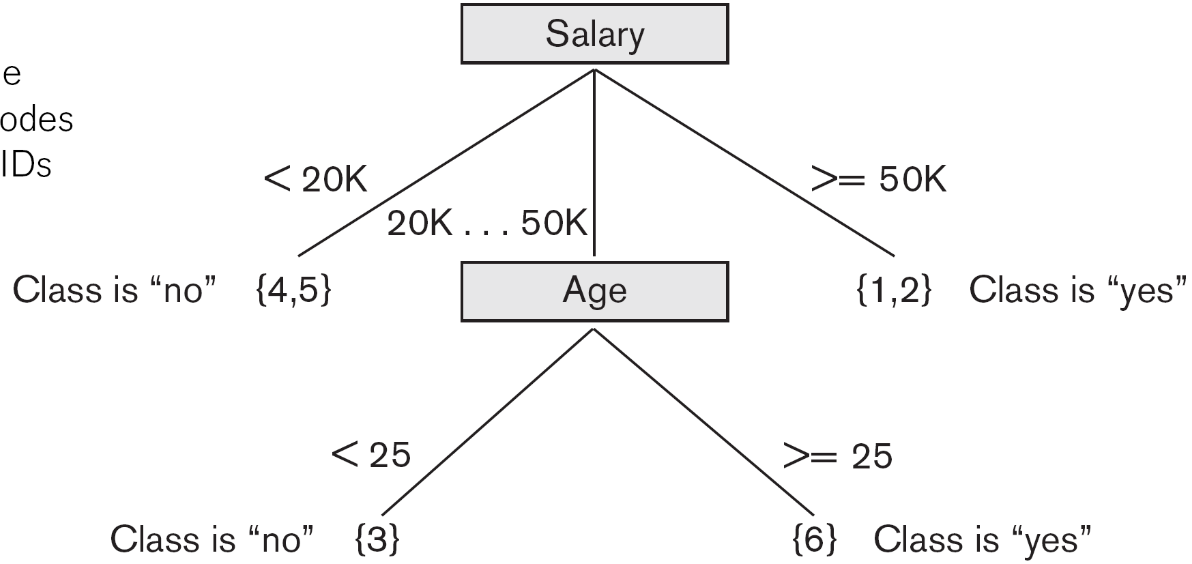

Figure 28.7
Decision tree based on sample training data where the leaf nodes are represented by a set of RIDs of the partitioned records.

An Example Rule

- Here is one of the rules extracted from the decision tree of Figure 28.7.

  IF 50K > salary >= 20K

  AND age >=25

  THEN class is "yes"

Clustering

- Unsupervised learning or clustering builds models from data without predefined classes.
- The goal is to place records into groups where the records in a group are highly similar to each other and dissimilar to records in other groups.
- The **k-Means** algorithm is a simple yet effective clustering technique.

Additional Data Mining Methods

- **Sequential pattern analysis**
- **Time Series Analysis**
- **Regression**
- **Neural Networks**
- **Genetic Algorithms**

Sequential Pattern Analysis

- Transactions ordered by time of purchase form a sequence of **itemsets**.
- The problem is to find all **subsequences** from a given set of sequences that have a minimum support.
- The sequence S_1, S_2, S_3, .. is a predictor of the fact that a customer purchasing itemset S_1 is likely to buy S_2 , and then S_3, and so on.

Time Series Analysis

- **Time series** are sequences of events. For example, the closing price of a stock is an event that occurs each day of the week.
- Time series analysis can be used to identify the price trends of a stock or mutual fund.
- Time series analysis is an extended functionality of **temporal** data management.

Regression Analysis

- A **regression equation** estimates a **dependent** variable using a set of **independent** variables and a set of constants.
- The independent variables as well as the dependent variable are numeric.
- A regression equation can be written in the form $Y=f(x_1,x_2,\ldots,x_n)$ where Y is the dependent variable.
- If f is linear in the domain variables x_i, the equation is call a **linear regression equation**.

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Neural Networks

- A **neural network** is a set of interconnected nodes designed to imitate the functioning of the brain.
- **Node connections** have **weights** which are modified during the learning process.
- Neural networks can be used for supervised learning and unsupervised clustering.
- The output of a neural network is **quantitative** and not easily understood.

Genetic Learning

- **Genetic learning** is based on the theory of evolution.
- An initial population of several candidate solutions is provided to the learning model.
- A fitness function defines which solutions survive from one generation to the next.
- **Crossover, mutation** and **selection** are used to create new population elements.

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Data Mining Applications

- **Marketing**
  - Marketing strategies and consumer behavior
- **Finance**
  - Fraud detection, creditworthiness and investment analysis
- **Manufacturing**
  - Resource optimization
- **Health**
  - Image analysis, side effects of drug, and treatment effectiveness

Recap

- Data Mining
- Data Warehousing
- Knowledge Discovery in Databases (KDD)
- Goals of Data Mining and Knowledge Discovery
- Association Rules
- Additional Data Mining Algorithms
  - Sequential pattern analysis
  - Time Series Analysis
  - Regression
  - Neural Networks
  - Genetic Algorithms

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