Paper Code: BCA 302 **L T C**
Paper ID: 20302 **3 1 4**
Paper: Data warehouse and data mining
Pre-requisites:
• Information System Concepts

Objectives: This course is an attempt to provide you with the basic information about data ware house and their development. This course also provides the basic conceptual background necessary to design and develop data ware house applications.

INSTRUCTIONS TO PAPER SETTERS: Maximum Marks: 75

1. Question No. 1 should be compulsory and cover the entire syllabus. This question should have objective or short answer type questions. It should be of 25 marks.
2. Apart from Question No. 1, rest of the paper shall consist of four units as per the syllabus.
3. Every unit should have two questions. However, student may be asked to attempt only 1 question from each unit.
4. Each question should be 12.5 marks

UNIT – I

Data mining: Introduction, Data mining – on what kind of data, data mining functionalities – what kind of patterns to be mined, Classification of data mining systems, data mining task primitives, integration of a data mining systems with a database or data warehouse systems, major issues in data mining.

Data preprocessing: Descriptive data summarization, data cleaning, data integration and transformation, data reduction, data descretization and concept hierarchy generation. **[No. of Hrs: 11]**

UNIT – II

Data warehouse and OLAP technology: What is data warehouse, A multidimensional data model, data warehouse architecture, data warehouse implementation, data warehouse usage, OLAP, OLAM

Mining frequent patterns, association and correlation, efficient and scalable frequent itemset mining methods, From association mining to correlation analysis. **[No. of Hrs: 11]**

UNIT – III

Classification and prediction: Introduction, issues, classification by decision tree induction, rule based classification, classification by back propagation, lazy learners, other classification methods, Prediction: accuracy and error measures, evaluating the accuracy of a classifier or predictor.

Cluster Analysis: Types of data in cluster analysis, a categorization of major clustering methods, partitioning methods. **[No. of Hrs: 11]**

UNIT – IV

Mining complex types of data: Multidimensional analysis and descriptive mining of complex data objects, mining spatial database, multimedia database, mining World Wide Web. Applications and trends in data mining: Data mining applications, data mining system products and research prototypes, social impact of data mining, trends in data mining. **[No. of Hrs: 11]**

Data Warehousing - Overview

The term "Data Warehouse" was first coined by Bill Inmon in 1990. According to Inmon, a data warehouse is a subject oriented, integrated, time-variant, and non-volatile collection of data. This data helps analysts to take informed decisions in an organization.

An operational database undergoes frequent changes on a daily basis on account of the transactions that take place. Suppose a business executive wants to analyze previous feedback on any data such as a product, a supplier, or any consumer data, then the executive will have no data available to analyze because the previous data has been updated due to transactions.

A data warehouses provides us generalized and consolidated data in multidimensional view. Along with generalized and consolidated view of data, a data warehouses also provides us Online Analytical Processing (OLAP) tools. These tools help us in interactive and effective analysis of data in a multidimensional space. This analysis results in data generalization and data mining.

Data mining functions such as association, clustering, classification, prediction can be integrated with OLAP operations to enhance the interactive mining of knowledge at multiple level of abstraction. That's why data warehouse has now become an important platform for data analysis and online analytical processing.

Understanding a Data Warehouse

- A data warehouse is a database, which is kept separate from the organization's operational database.
- There is no frequent updating done in a data warehouse.
- It possesses consolidated historical data, which helps the organization to analyze its business.
- A data warehouse helps executives to organize, understand, and use their data to take strategic decisions.
- Data warehouse systems help in the integration of diversity of application systems.
- A data warehouse system helps in consolidated historical data analysis.

Why a Data Warehouse is Separated from Operational Databases

A data warehouses is kept separate from operational databases due to the following reasons −

- An operational database is constructed for well-known tasks and workloads such as searching particular records, indexing, etc. In contract, data warehouse queries are often complex and they present a general form of data.
- Operational databases support concurrent processing of multiple transactions. Concurrency control and recovery mechanisms are required for operational databases to ensure robustness and consistency of the database.
- An operational database query allows to read and modify operations, while an OLAP query needs only **read only** access of stored data.
- An operational database maintains current data. On the other hand, a data warehouse maintains historical data.

Data Warehouse Features

The key features of a data warehouse are discussed below −

- **Subject Oriented** − A data warehouse is subject oriented because it provides information around a subject rather than the organization's ongoing operations. These subjects can be product, customers, suppliers, sales, revenue, etc. A data warehouse does not focus on the ongoing operations, rather it focuses on modelling and analysis of data for decision making.
- **Integrated** − A data warehouse is constructed by integrating data from heterogeneous sources such as relational databases, flat files, etc. This integration enhances the effective analysis of data.
- **Time Variant** − The data collected in a data warehouse is identified with a particular time period. The data in a data warehouse provides information from the historical point of view.
- **Non-volatile** − Non-volatile means the previous data is not erased when new data is added to it. A data warehouse is kept separate from the operational database and therefore frequent changes in operational database is not reflected in the data warehouse.

Note − A data warehouse does not require transaction processing, recovery, and concurrency controls, because it is physically stored and separate from the operational database.

Data Warehouse Applications

As discussed before, a data warehouse helps business executives to organize, analyze, and use their data for decision making. A data warehouse serves as a sole part of a plan-execute-assess "closed-loop" feedback system for the enterprise management. Data warehouses are widely used in the following fields −

- Financial services
- Banking services
- Consumer goods
- Retail sectors
- Controlled manufacturing

Types of Data Warehouse

Information processing, analytical processing, and data mining are the three types of data warehouse applications that are discussed below −

- **Information Processing** − A data warehouse allows to process the data stored in it. The data can be processed by means of querying, basic statistical analysis, reporting using crosstabs, tables, charts, or graphs.
- **Analytical Processing** − A data warehouse supports analytical processing of the information stored in it. The data can be analyzed by means of basic OLAP operations, including slice-and-dice, drill down, drill up, and pivoting.
- **Data Mining** − Data mining supports knowledge discovery by finding hidden patterns and associations, constructing analytical models, performing classification and prediction. These mining results can be presented using the visualization tools.

Sr.No.	Data Warehouse (OLAP)	Operational Database(OLTP)
1	It involves historical processing of	It involves day-to-day processing.

	information.	
2	OLAP systems are used by knowledge workers such as executives, managers, and analysts.	OLTP systems are used by clerks, DBAs, or database professionals.
3	It is used to analyze the business.	It is used to run the business.
4	It focuses on Information out.	It focuses on Data in.
5	It is based on Star Schema, Snowflake Schema, and Fact Constellation Schema.	It is based on Entity Relationship Model.
6	It focuses on Information out.	It is application oriented.
7	It contains historical data.	It contains current data.
8	It provides summarized and consolidated data.	It provides primitive and highly detailed data.
9	It provides summarized and multidimensional view of data.	It provides detailed and flat relational view of data.
10	The number of users is in hundreds.	The number of users is in thousands.
11	The number of records accessed is in millions.	The number of records accessed is in tens.

12	The database size is from 100GB to 100 TB.	The database size is from 100 MB to 100 GB.
13	These are highly flexible.	It provides high performance.

Data Warehousing - Concepts

What is Data Warehousing?

Data warehousing is the process of constructing and using a data warehouse. A data warehouse is constructed by integrating data from multiple heterogeneous sources that support analytical reporting, structured and/or ad hoc queries, and decision making. Data warehousing involves data cleaning, data integration, and data consolidations.

Using Data Warehouse Information

There are decision support technologies that help utilize the data available in a data warehouse. These technologies help executives to use the warehouse quickly and effectively. They can gather data, analyze it, and take decisions based on the information present in the warehouse. The information gathered in a warehouse can be used in any of the following domains −

- **Tuning Production Strategies** − The product strategies can be well tuned by repositioning the products and managing the product portfolios by comparing the sales quarterly or yearly.
- **Customer Analysis** − Customer analysis is done by analyzing the customer's buying preferences, buying time, budget cycles, etc.
- **Operations Analysis** − Data warehousing also helps in customer relationship management, and making environmental corrections. The information also allows us to analyze business operations.

Integrating Heterogeneous Databases

To integrate heterogeneous databases, we have two approaches −

- Query-driven Approach

- Update-driven Approach

Query-Driven Approach

This is the traditional approach to integrate heterogeneous databases. This approach was used to build wrappers and integrators on top of multiple heterogeneous databases. These integrators are also known as mediators.

Process of Query-Driven Approach

- When a query is issued to a client side, a metadata dictionary translates the query into an appropriate form for individual heterogeneous sites involved.
- Now these queries are mapped and sent to the local query processor.
- The results from heterogeneous sites are integrated into a global answer set.

Disadvantages

- Query-driven approach needs complex integration and filtering processes.
- This approach is very inefficient.
- It is very expensive for frequent queries.
- This approach is also very expensive for queries that require aggregations.

Update-Driven Approach

This is an alternative to the traditional approach. Today's data warehouse systems follow update-driven approach rather than the traditional approach discussed earlier. In update-driven approach, the information from multiple heterogeneous sources are integrated in advance and are stored in a warehouse. This information is available for direct querying and analysis.

Advantages

This approach has the following advantages −

- This approach provide high performance.
- The data is copied, processed, integrated, annotated, summarized and restructured in semantic data store in advance.
- Query processing does not require an interface to process data at local sources.

Functions of Data Warehouse Tools and Utilities

The following are the functions of data warehouse tools and utilities −

- **Data Extraction** − Involves gathering data from multiple heterogeneous sources.
- **Data Cleaning** − Involves finding and correcting the errors in data.
- **Data Transformation** − Involves converting the data from legacy format to warehouse format.
- **Data Loading** − Involves sorting, summarizing, consolidating, checking integrity, and building indices and partitions.
- **Refreshing** − Involves updating from data sources to warehouse.

Note − Data cleaning and data transformation are important steps in improving the quality of data and data mining results.

Data Warehousing - Terminologies

In this chapter, we will discuss some of the most commonly used terms in data warehousing.

Metadata

Metadata is simply defined as data about data. The data that are used to represent other data is known as metadata. For example, the index of a book serves as a metadata for the contents in the book. In other words, we can say that metadata is the summarized data that leads us to the detailed data.

In terms of data warehouse, we can define metadata as following −

- Metadata is a road-map to data warehouse.
- Metadata in data warehouse defines the warehouse objects.
- Metadata acts as a directory. This directory helps the decision support system to locate the contents of a data warehouse.

Metadata Repository

Metadata repository is an integral part of a data warehouse system. It contains the following metadata −

- **Business metadata** − It contains the data ownership information, business definition, and changing policies.
- **Operational metadata** − It includes currency of data and data lineage. Currency of data refers to the data being active, archived, or purged. Lineage of data means history of data migrated and transformation applied on it.
- **Data for mapping from operational environment to data warehouse** − It metadata includes source databases and their contents, data extraction, data partition, cleaning, transformation rules, data refresh and purging rules.
- **The algorithms for summarization** − It includes dimension algorithms, data on granularity, aggregation, summarizing, etc.

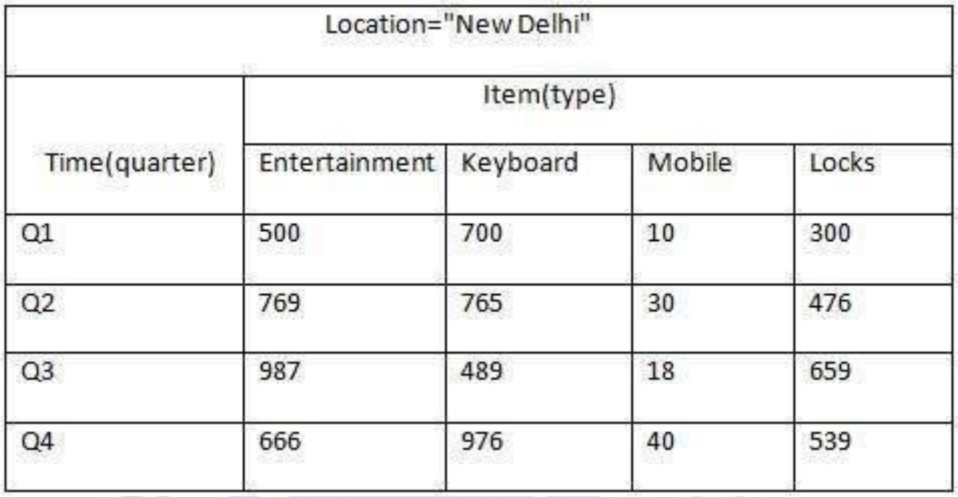
Data Cube

A data cube helps us represent data in multiple dimensions. It is defined by dimensions and facts. The dimensions are the entities with respect to which an enterprise preserves the records.

Illustration of Data Cube

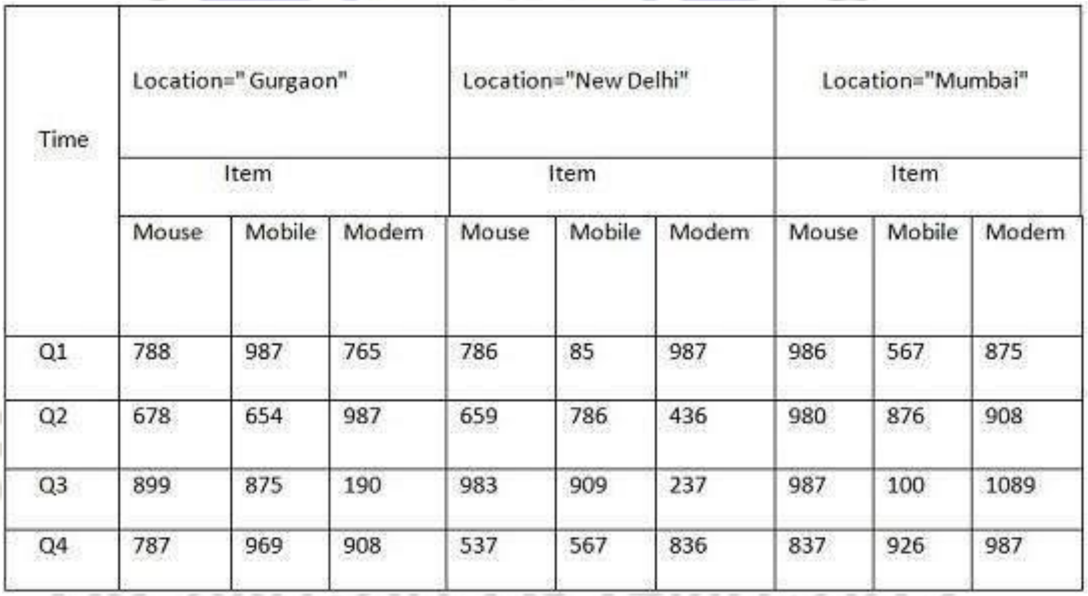
Suppose a company wants to keep track of sales records with the help of sales data warehouse with respect to time, item, branch, and location. These dimensions allow to keep track of monthly sales and at which branch the items were sold. There is a table associated with each dimension. This table is known as dimension table. For example, "item" dimension table may have attributes such as item_name, item_type, and item_brand.

The following table represents the 2-D view of Sales Data for a company with respect to time, item, and location dimensions.



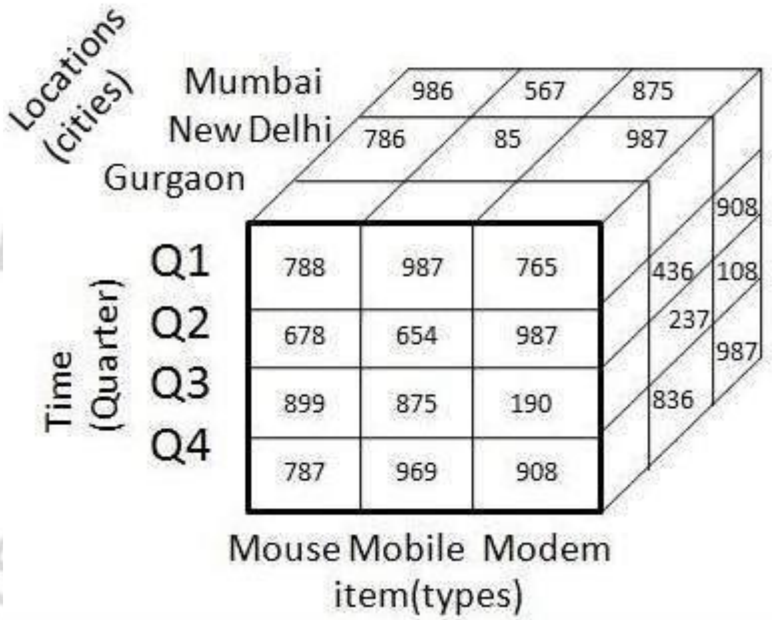
Location="New Delhi"				
Time(quarter)	Item(type)			
	Entertainment	Keyboard	Mobile	Locks
Q1	500	700	10	300
Q2	769	765	30	476
Q3	987	489	18	659
Q4	666	976	40	539

But here in this 2-D table, we have records with respect to time and item only. The sales for New Delhi are shown with respect to time, and item dimensions according to type of items sold. If we want to view the sales data with one more dimension, say, the location dimension, then the 3-D view would be useful. The 3-D view of the sales data with respect to time, item, and location is shown in the table below −



Time	Location=" Gurgaon"			Location="New Delhi"			Location="Mumbai"		
	Item			Item			Item		
	Mouse	Mobile	Modem	Mouse	Mobile	Modem	Mouse	Mobile	Modem
Q1	788	987	765	786	85	987	986	567	875
Q2	678	654	987	659	786	436	980	876	908
Q3	899	875	190	983	909	237	987	100	1089
Q4	787	969	908	537	567	836	837	926	987

The above 3-D table can be represented as 3-D data cube as shown in the following figure −



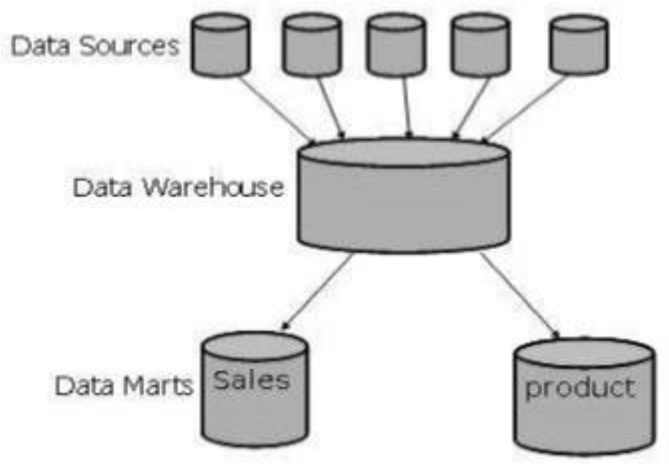
Data Mart

Data marts contain a subset of organization-wide data that is valuable to specific groups of people in an organization. In other words, a data mart contains only those data that is specific to a particular group. For example, the marketing data mart may contain only data related to items, customers, and sales. Data marts are confined to subjects.

Points to Remember About Data Marts

- Windows-based or Unix/Linux-based servers are used to implement data marts. They are implemented on low-cost servers.
- The implementation cycle of a data mart is measured in short periods of time, i.e., in weeks rather than months or years.
- The life cycle of data marts may be complex in the long run, if their planning and design are not organization-wide.
- Data marts are small in size.
- Data marts are customized by department.
- The source of a data mart is departmentally structured data warehouse.
- Data marts are flexible.

The following figure shows a graphical representation of data marts.



Virtual Warehouse

The view over an operational data warehouse is known as virtual warehouse. It is easy to build a virtual warehouse. Building a virtual warehouse requires excess capacity on operational database servers.

Data Warehousing - Delivery Process

A data warehouse is never static; it evolves as the business expands. As the business evolves, its requirements keep changing and therefore a data warehouse must be designed to ride with these changes. Hence a data warehouse system needs to be flexible.

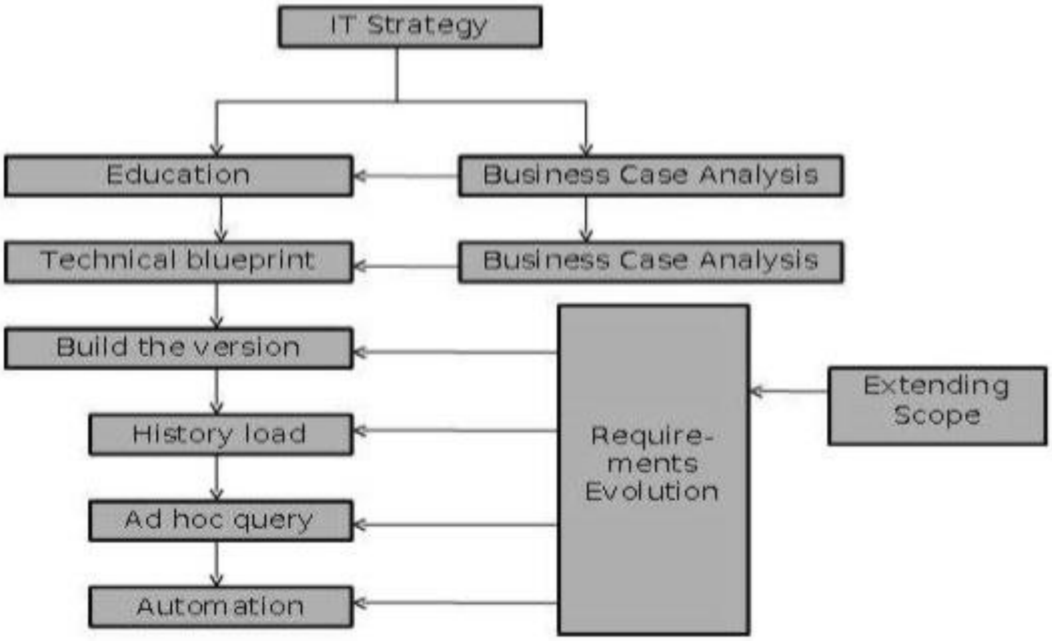
Ideally there should be a delivery process to deliver a data warehouse. However data warehouse projects normally suffer from various issues that make it difficult to complete tasks and deliverables in the strict and ordered fashion demanded by the waterfall method. Most of the times, the requirements are not understood completely. The architectures, designs, and build components can be completed only after gathering and studying all the requirements.

Delivery Method

The delivery method is a variant of the joint application development approach adopted for the delivery of a data warehouse. We have staged the data warehouse delivery process to minimize risks. The approach that we will discuss here does not reduce the overall delivery time-scales but ensures the business benefits are delivered incrementally through the development process.

Note − The delivery process is broken into phases to reduce the project and delivery risk.

The following diagram explains the stages in the delivery process −



IT Strategy

Data warehouse are strategic investments that require a business process to generate benefits. IT Strategy is required to procure and retain funding for the project.

Business Case

The objective of business case is to estimate business benefits that should be derived from using a data warehouse. These benefits may not be quantifiable but the projected benefits need to be clearly stated. If a data warehouse does not have a clear business case, then the business tends to suffer from credibility problems at some stage during the delivery process. Therefore in data warehouse projects, we need to understand the business case for investment.

Education and Prototyping

Organizations experiment with the concept of data analysis and educate themselves on the value of having a data warehouse before settling for a solution. This is addressed by prototyping. It helps in understanding the feasibility and benefits of a data warehouse. The prototyping activity on a small scale can promote educational process as long as −

- The prototype addresses a defined technical objective.

- The prototype can be thrown away after the feasibility concept has been shown.
- The activity addresses a small subset of eventual data content of the data warehouse.
- The activity timescale is non-critical.

The following points are to be kept in mind to produce an early release and deliver business benefits.

- Identify the architecture that is capable of evolving.
- Focus on business requirements and technical blueprint phases.
- Limit the scope of the first build phase to the minimum that delivers business benefits.
- Understand the short-term and medium-term requirements of the data warehouse.

Business Requirements

To provide quality deliverables, we should make sure the overall requirements are understood. If we understand the business requirements for both short-term and medium-term, then we can design a solution to fulfil short-term requirements. The short-term solution can then be grown to a full solution.

The following aspects are determined in this stage −

- The business rule to be applied on data.
- The logical model for information within the data warehouse.
- The query profiles for the immediate requirement.
- The source systems that provide this data.

Technical Blueprint

This phase need to deliver an overall architecture satisfying the long term requirements. This phase also deliver the components that must be implemented in a short term to derive any business benefit. The blueprint need to identify the followings.

- The overall system architecture.
- The data retention policy.
- The backup and recovery strategy.

- The server and data mart architecture.
- The capacity plan for hardware and infrastructure.
- The components of database design.

Building the Version

In this stage, the first production deliverable is produced. This production deliverable is the smallest component of a data warehouse. This smallest component adds business benefit.

History Load

This is the phase where the remainder of the required history is loaded into the data warehouse. In this phase, we do not add new entities, but additional physical tables would probably be created to store increased data volumes.

Let us take an example. Suppose the build version phase has delivered a retail sales analysis data warehouse with 2 months' worth of history. This information will allow the user to analyze only the recent trends and address the short-term issues. The user in this case cannot identify annual and seasonal trends. To help him do so, last 2 years' sales history could be loaded from the archive. Now the 40GB data is extended to 400GB.

Note − The backup and recovery procedures may become complex, therefore it is recommended to perform this activity within a separate phase.

Ad hoc Query

In this phase, we configure an ad hoc query tool that is used to operate a data warehouse. These tools can generate the database query.

Note − It is recommended not to use these access tools when the database is being substantially modified.

Automation

In this phase, operational management processes are fully automated. These would include −

- Transforming the data into a form suitable for analysis.
- Monitoring query profiles and determining appropriate aggregations to maintain system performance.
- Extracting and loading data from different source systems.

- Generating aggregations from predefined definitions within the data warehouse.
- Backing up, restoring, and archiving the data.

Extending Scope

In this phase, the data warehouse is extended to address a new set of business requirements. The scope can be extended in two ways −

- By loading additional data into the data warehouse.
- By introducing new data marts using the existing information.

Note − This phase should be performed separately, since it involves substantial efforts and complexity.

Requirements Evolution

From the perspective of delivery process, the requirements are always changeable. They are not static. The delivery process must support this and allow these changes to be reflected within the system.

This issue is addressed by designing the data warehouse around the use of data within business processes, as opposed to the data requirements of existing queries.

The architecture is designed to change and grow to match the business needs, the process operates as a pseudo-application development process, where the new requirements are continually fed into the development activities and the partial deliverables are produced. These partial deliverables are fed back to the users and then reworked ensuring that the overall system is continually updated to meet the business needs.

Data Warehousing - System Processes

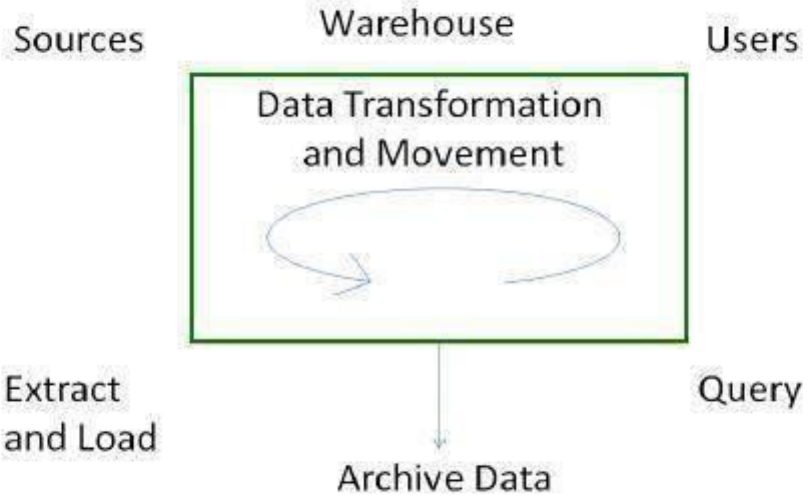
We have a fixed number of operations to be applied on the operational databases and we have well-defined techniques such as **use normalized data**, **keep table small**, etc. These techniques are suitable for delivering a solution. But in case of decision-support systems, we do not know what query and operation needs to be executed in future. Therefore techniques applied on operational databases are not suitable for data warehouses.

In this chapter, we will discuss how to build data warehousing solutions on top open-system technologies like Unix and relational databases.

Process Flow in Data Warehouse

There are four major processes that contribute to a data warehouse −

- Extract and load the data.
- Cleaning and transforming the data.
- Backup and archive the data.
- Managing queries and directing them to the appropriate data sources.



Extract and Load Process

Data extraction takes data from the source systems. Data load takes the extracted data and loads it into the data warehouse.

Note − Before loading the data into the data warehouse, the information extracted from the external sources must be reconstructed.

Controlling the Process

Controlling the process involves determining when to start data extraction and the consistency check on data. Controlling process ensures that the tools, the logic modules, and the programs are executed in correct sequence and at correct time.

When to Initiate Extract

Data needs to be in a consistent state when it is extracted, i.e., the data warehouse should represent a single, consistent version of the information to the user.

For example, in a customer profiling data warehouse in telecommunication sector, it is illogical to merge the list of customers at 8 pm on Wednesday from a customer database with the customer subscription events up to 8 pm on Tuesday. This would mean that we are finding the customers for whom there are no associated subscriptions.

Loading the Data

After extracting the data, it is loaded into a temporary data store where it is cleaned up and made consistent.

Note − Consistency checks are executed only when all the data sources have been loaded into the temporary data store.

Clean and Transform Process

Once the data is extracted and loaded into the temporary data store, it is time to perform Cleaning and Transforming. Here is the list of steps involved in Cleaning and Transforming −

- Clean and transform the loaded data into a structure
- Partition the data
- Aggregation

Clean and Transform the Loaded Data into a Structure

Cleaning and transforming the loaded data helps speed up the queries. It can be done by making the data consistent −

- within itself.
- with other data within the same data source.
- with the data in other source systems.

- with the existing data present in the warehouse.

Transforming involves converting the source data into a structure. Structuring the data increases the query performance and decreases the operational cost. The data contained in a data warehouse must be transformed to support performance requirements and control the ongoing operational costs.

Partition the Data

It will optimize the hardware performance and simplify the management of data warehouse. Here we partition each fact table into multiple separate partitions.

Aggregation

Aggregation is required to speed up common queries. Aggregation relies on the fact that most common queries will analyze a subset or an aggregation of the detailed data.

Backup and Archive the Data

In order to recover the data in the event of data loss, software failure, or hardware failure, it is necessary to keep regular back ups. Archiving involves removing the old data from the system in a format that allow it to be quickly restored whenever required.

For example, in a retail sales analysis data warehouse, it may be required to keep data for 3 years with the latest 6 months data being kept online. In such as scenario, there is often a requirement to be able to do month-on-month comparisons for this year and last year. In this case, we require some data to be restored from the archive.

Query Management Process

This process performs the following functions −

- manages the queries.
- helps speed up the execution time of queris.
- directs the queries to their most effective data sources.
- ensures that all the system sources are used in the most effective way.
- monitors actual query profiles.

The information generated in this process is used by the warehouse management process to determine which aggregations to generate. This process does not generally operate during the regular load of information into data warehouse.

Data Warehousing - Architecture

In this chapter, we will discuss the business analysis framework for the data warehouse design and architecture of a data warehouse.

Business Analysis Framework

The business analyst get the information from the data warehouses to measure the performance and make critical adjustments in order to win over other business holders in the market. Having a data warehouse offers the following advantages −

- Since a data warehouse can gather information quickly and efficiently, it can enhance business productivity.
- A data warehouse provides us a consistent view of customers and items, hence, it helps us manage customer relationship.
- A data warehouse also helps in bringing down the costs by tracking trends, patterns over a long period in a consistent and reliable manner.

To design an effective and efficient data warehouse, we need to understand and analyze the business needs and construct a **business analysis framework**. Each person has different views regarding the design of a data warehouse. These views are as follows −

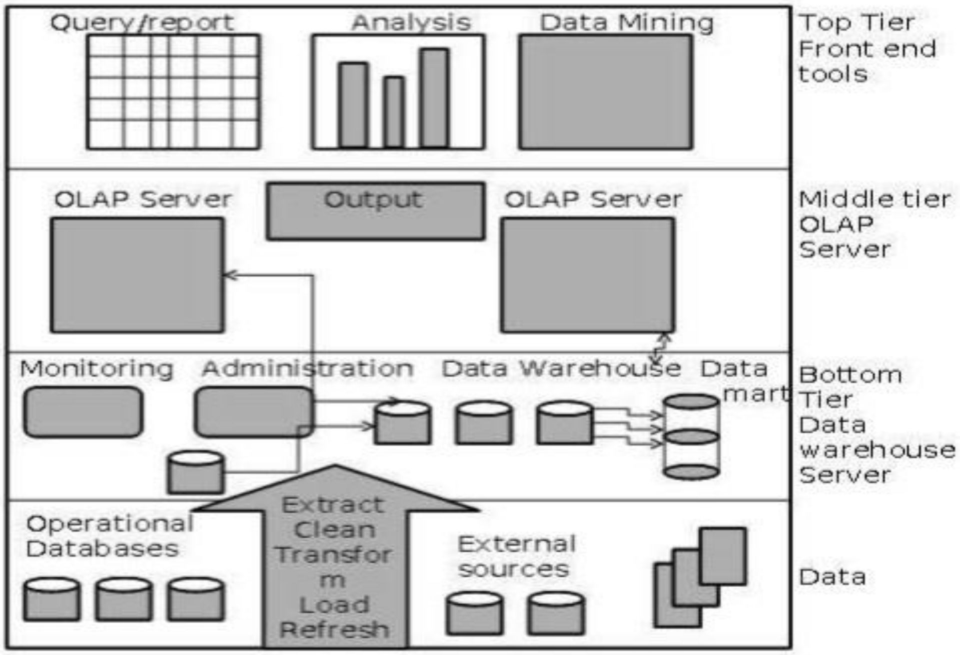
- **The top-down view** − This view allows the selection of relevant information needed for a data warehouse.
- **The data source view** − This view presents the information being captured, stored, and managed by the operational system.
- **The data warehouse view** − This view includes the fact tables and dimension tables. It represents the information stored inside the data warehouse.
- **The business query view** − It is the view of the data from the viewpoint of the end-user.

Three-Tier Data Warehouse Architecture

Generally a data warehouses adopts a three-tier architecture. Following are the three tiers of the data warehouse architecture.

- **Bottom Tier** − The bottom tier of the architecture is the data warehouse database server. It is the relational database system. We use the back end tools and utilities to feed data into the bottom tier. These back end tools and utilities perform the Extract, Clean, Load, and refresh functions.
- **Middle Tier** − In the middle tier, we have the OLAP Server that can be implemented in either of the following ways.
  - By Relational OLAP (ROLAP), which is an extended relational database management system. The ROLAP maps the operations on multidimensional data to standard relational operations.
  - By Multidimensional OLAP (MOLAP) model, which directly implements the multidimensional data and operations.
- **Top-Tier** − This tier is the front-end client layer. This layer holds the query tools and reporting tools, analysis tools and data mining tools.

The following diagram depicts the three-tier architecture of data warehouse −



Data Warehouse Models

From the perspective of data warehouse architecture, we have the following data warehouse models −

- Virtual Warehouse
- Data mart
- Enterprise Warehouse

Virtual Warehouse

The view over an operational data warehouse is known as a virtual warehouse. It is easy to build a virtual warehouse. Building a virtual warehouse requires excess capacity on operational database servers.

Data Mart

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In other words, we can claim that data marts contain data specific to a particular group. For example, the marketing data mart may contain data related to items, customers, and sales. Data marts are confined to subjects.

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- The implementation data mart cycles is measured in short periods of time, i.e., in weeks rather than months or years.
- The life cycle of a data mart may be complex in long run, if its planning and design are not organization-wide.
- Data marts are small in size.
- Data marts are customized by department.
- The source of a data mart is departmentally structured data warehouse.
- Data mart are flexible.

Enterprise Warehouse

- An enterprise warehouse collects all the information and the subjects spanning an entire organization
- It provides us enterprise-wide data integration.
- The data is integrated from operational systems and external information providers.
- This information can vary from a few gigabytes to hundreds of gigabytes, terabytes or beyond.

Load Manager

This component performs the operations required to extract and load process.

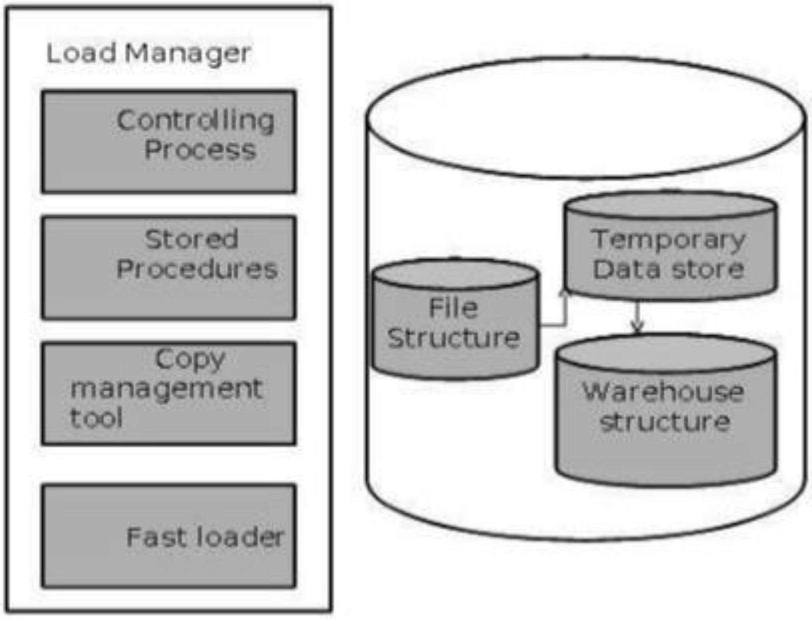
The size and complexity of the load manager varies between specific solutions from one data warehouse to other.

Load Manager Architecture

The load manager performs the following functions −

- Extract the data from source system.
- Fast Load the extracted data into temporary data store.

- Perform simple transformations into structure similar to the one in the data warehouse.



Extract Data from Source

The data is extracted from the operational databases or the external information providers. Gateways is the application programs that are used to extract data. It is supported by underlying DBMS and allows client program to generate SQL to be executed at a server. Open Database Connection(ODBC), Java Database Connection (JDBC), are examples of gateway.

Fast Load

- In order to minimize the total load window the data need to be loaded into the warehouse in the fastest possible time.
- The transformations affects the speed of data processing.
- It is more effective to load the data into relational database prior to applying transformations and checks.
- Gateway technology proves to be not suitable, since they tend not be performant when large data volumes are involved.

Simple Transformations

While loading it may be required to perform simple transformations. After this has been completed we are in position to do the complex checks. Suppose we are loading the EPOS sales transaction we need to perform the following checks:

- Strip out all the columns that are not required within the warehouse.
- Convert all the values to required data types.

Warehouse Manager

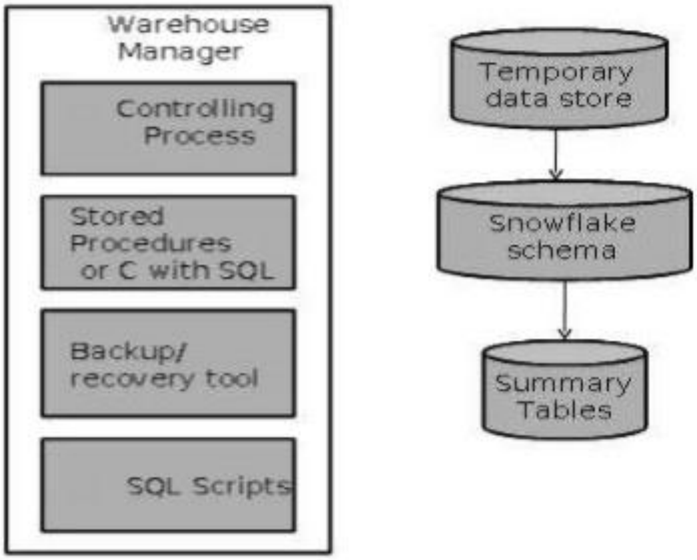
A warehouse manager is responsible for the warehouse management process. It consists of third-party system software, C programs, and shell scripts.

The size and complexity of warehouse managers varies between specific solutions.

Warehouse Manager Architecture

A warehouse manager includes the following −

- The controlling process
- Stored procedures or C with SQL
- Backup/Recovery tool
- SQL Scripts



Operations Performed by Warehouse Manager

- A warehouse manager analyzes the data to perform consistency and referential integrity checks.
- Creates indexes, business views, partition views against the base data.
- Generates new aggregations and updates existing aggregations. Generates normalizations.
- Transforms and merges the source data into the published data warehouse.
- Backup the data in the data warehouse.
- Archives the data that has reached the end of its captured life.

Note − A warehouse Manager also analyzes query profiles to determine index and aggregations are appropriate.

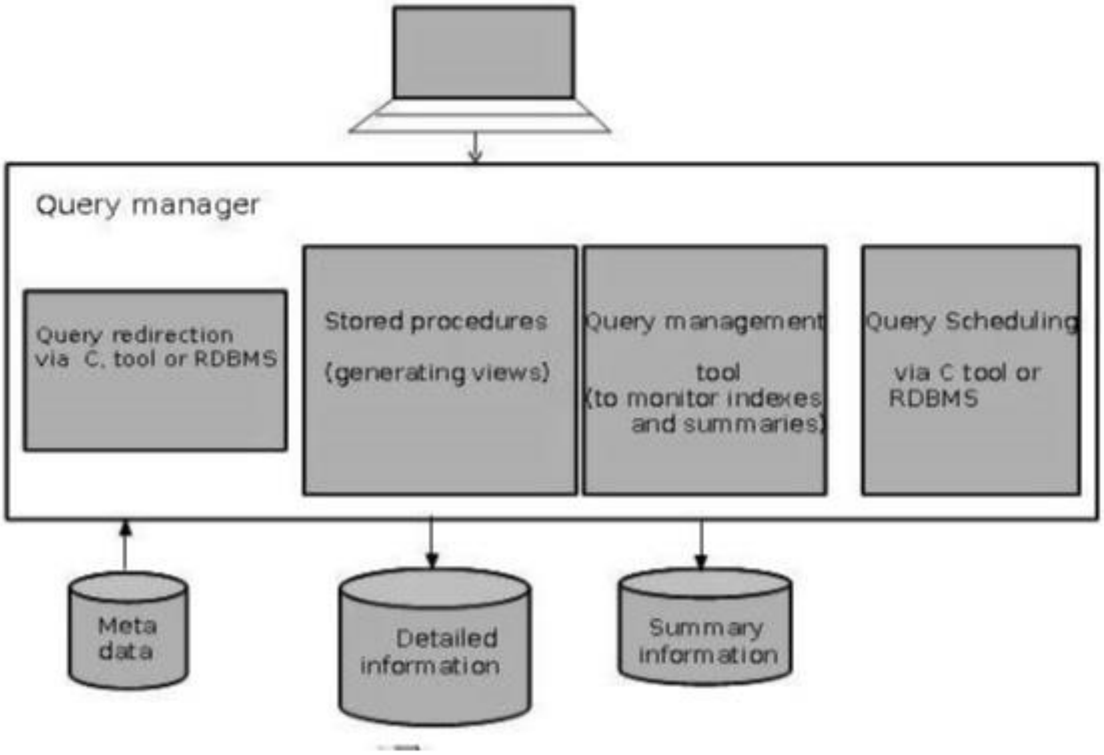
Query Manager

- Query manager is responsible for directing the queries to the suitable tables.
- By directing the queries to appropriate tables, the speed of querying and response generation can be increased.
- Query manager is responsible for scheduling the execution of the queries posed by the user.

Query Manager Architecture

The following screenshot shows the architecture of a query manager. It includes the following:

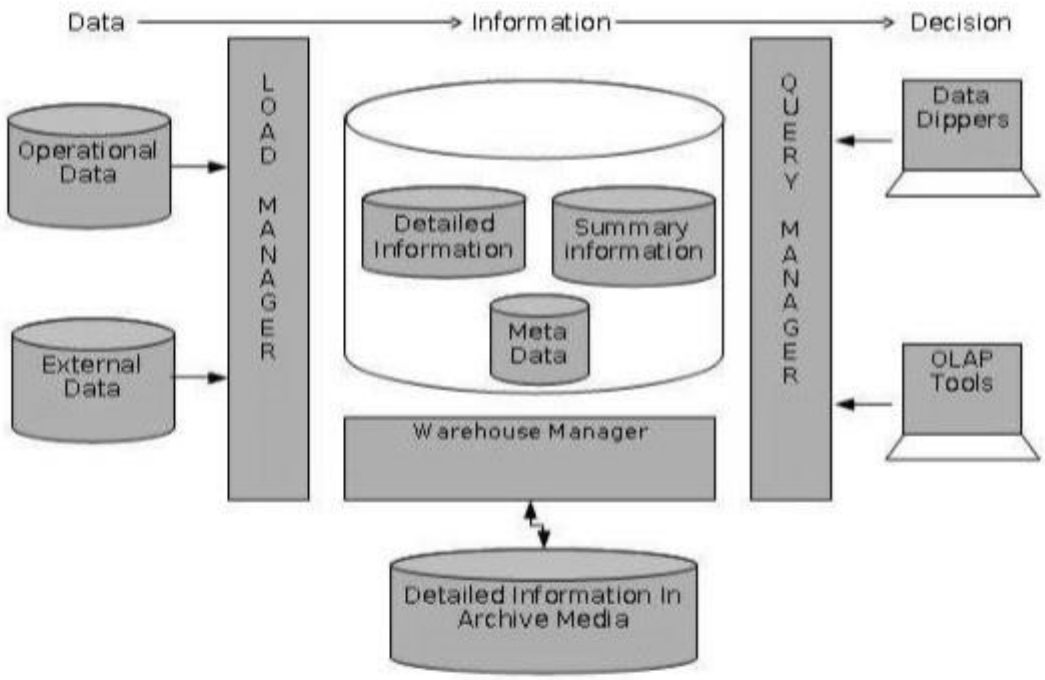
- Query redirection via C tool or RDBMS
- Stored procedures
- Query management tool
- Query scheduling via C tool or RDBMS
- Query scheduling via third-party software


Query manager
Query redirection via C, tool or RDBMS
Stored procedures (generating views)
Query management tool (to monitor indexes and summaries)
Query Scheduling via C tool or RDBMS
Meta data
Detailed information
Summary information

Detailed Information

Detailed information is not kept online, rather it is aggregated to the next level of detail and then archived to tape. The detailed information part of data warehouse keeps the detailed information in the starflake schema. Detailed information is loaded into the data warehouse to supplement the aggregated data.

The following diagram shows a pictorial impression of where detailed information is stored and how it is used.



Note − If detailed information is held offline to minimize disk storage, we should make sure that the data has been extracted, cleaned up, and transformed into starflake schema before it is archived.

Summary Information

Summary Information is a part of data warehouse that stores predefined aggregations. These aggregations are generated by the warehouse manager. Summary Information must be treated as transient. It changes on-the-go in order to respond to the changing query profiles.

The points to note about summary information are as follows −

- Summary information speeds up the performance of common queries.
- It increases the operational cost.
- It needs to be updated whenever new data is loaded into the data warehouse.
- It may not have been backed up, since it can be generated fresh from the detailed information.

Data Warehousing - OLAP

Online Analytical Processing Server (OLAP) is based on the multidimensional data model. It allows managers, and analysts to get an insight of the information through fast, consistent, and interactive access to information. This chapter cover the types of OLAP, operations on OLAP, difference between OLAP, and statistical databases and OLTP.

Types of OLAP Servers

We have four types of OLAP servers −

- Relational OLAP (ROLAP)
- Multidimensional OLAP (MOLAP)
- Hybrid OLAP (HOLAP)
- Specialized SQL Servers

Relational OLAP

ROLAP servers are placed between relational back-end server and client front-end tools. To store and manage warehouse data, ROLAP uses relational or extended-relational DBMS.

ROLAP includes the following −

- Implementation of aggregation navigation logic.
- Optimization for each DBMS back end.
- Additional tools and services.

Multidimensional OLAP

MOLAP uses array-based multidimensional storage engines for multidimensional views of data. With multidimensional data stores, the storage utilization may be low if the data set is sparse. Therefore, many MOLAP server use two levels of data storage representation to handle dense and sparse data sets.

Hybrid OLAP

Hybrid OLAP is a combination of both ROLAP and MOLAP. It offers higher scalability of ROLAP and faster computation of MOLAP. HOLAP servers allows to store the large data volumes of detailed information. The aggregations are stored separately in MOLAP store.

Specialized SQL Servers

Specialized SQL servers provide advanced query language and query processing support for SQL queries over star and snowflake schemas in a read-only environment.

OLAP Operations

Since OLAP servers are based on multidimensional view of data, we will discuss OLAP operations in multidimensional data.

Here is the list of OLAP operations −

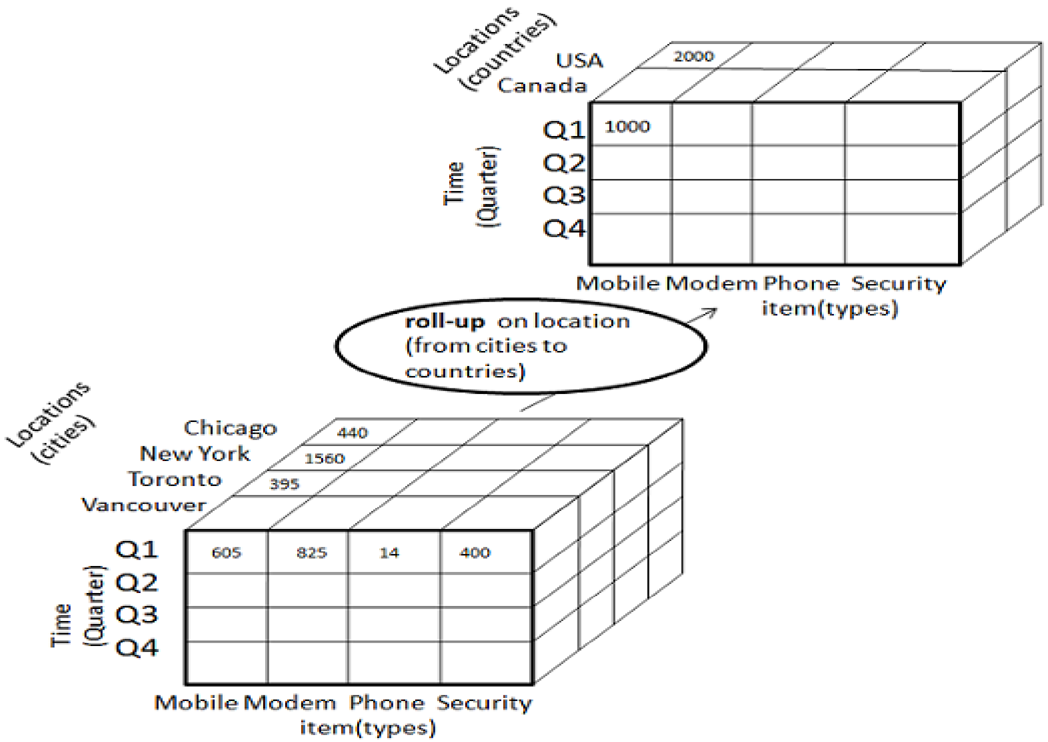
- Roll-up
- Drill-down
- Slice and dice
- Pivot (rotate)

Roll-up

Roll-up performs aggregation on a data cube in any of the following ways −

- By climbing up a concept hierarchy for a dimension
- By dimension reduction

The following diagram illustrates how roll-up works.



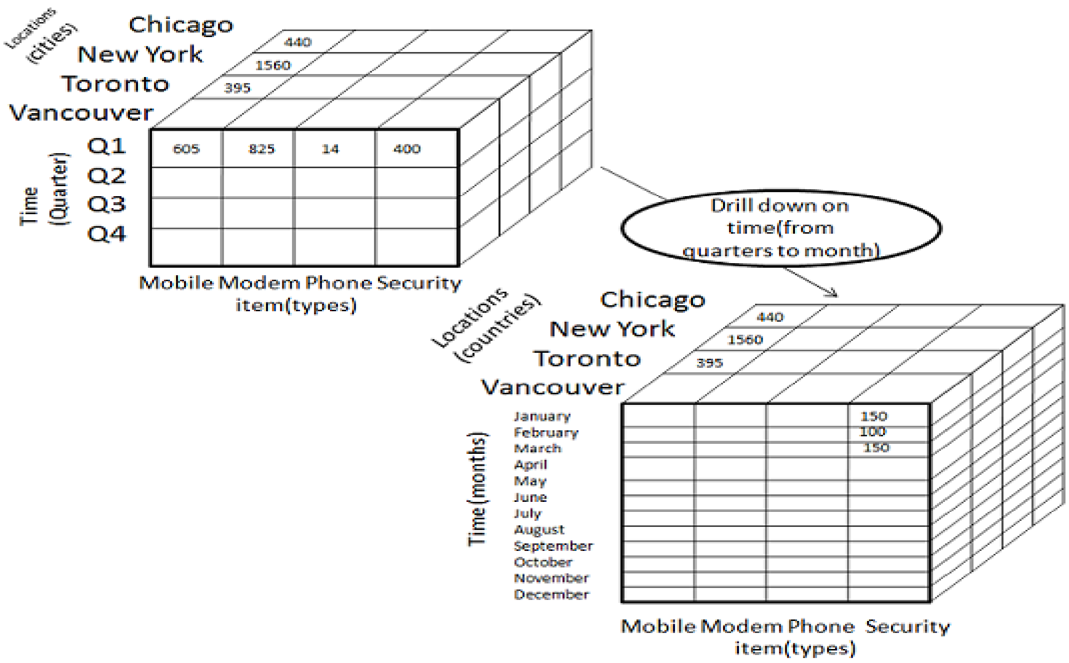
- Roll-up is performed by climbing up a concept hierarchy for the dimension location.
- Initially the concept hierarchy was "street < city < province < country".
- On rolling up, the data is aggregated by ascending the location hierarchy from the level of city to the level of country.
- The data is grouped into cities rather than countries.
- When roll-up is performed, one or more dimensions from the data cube are removed.

Drill-down

Drill-down is the reverse operation of roll-up. It is performed by either of the following ways −

- By stepping down a concept hierarchy for a dimension
- By introducing a new dimension.

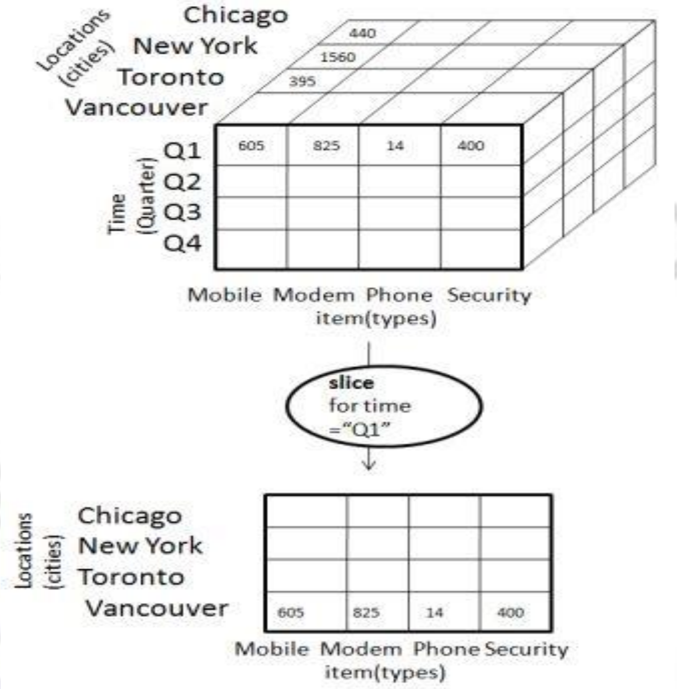
The following diagram illustrates how drill-down works −



- Drill-down is performed by stepping down a concept hierarchy for the dimension time.
- Initially the concept hierarchy was "day < month < quarter < year."
- On drilling down, the time dimension is descended from the level of quarter to the level of month.
- When drill-down is performed, one or more dimensions from the data cube are added.
- It navigates the data from less detailed data to highly detailed data.

Slice

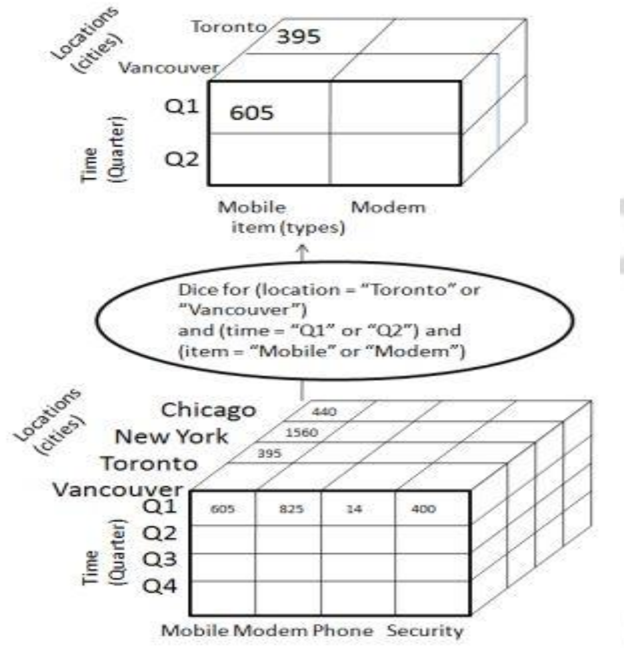
The slice operation selects one particular dimension from a given cube and provides a new sub-cube. Consider the following diagram that shows how slice works.



- Here Slice is performed for the dimension "time" using the criterion time = "Q1".
- It will form a new sub-cube by selecting one or more dimensions.

Dice

Dice selects two or more dimensions from a given cube and provides a new sub-cube. Consider the following diagram that shows the dice operation.

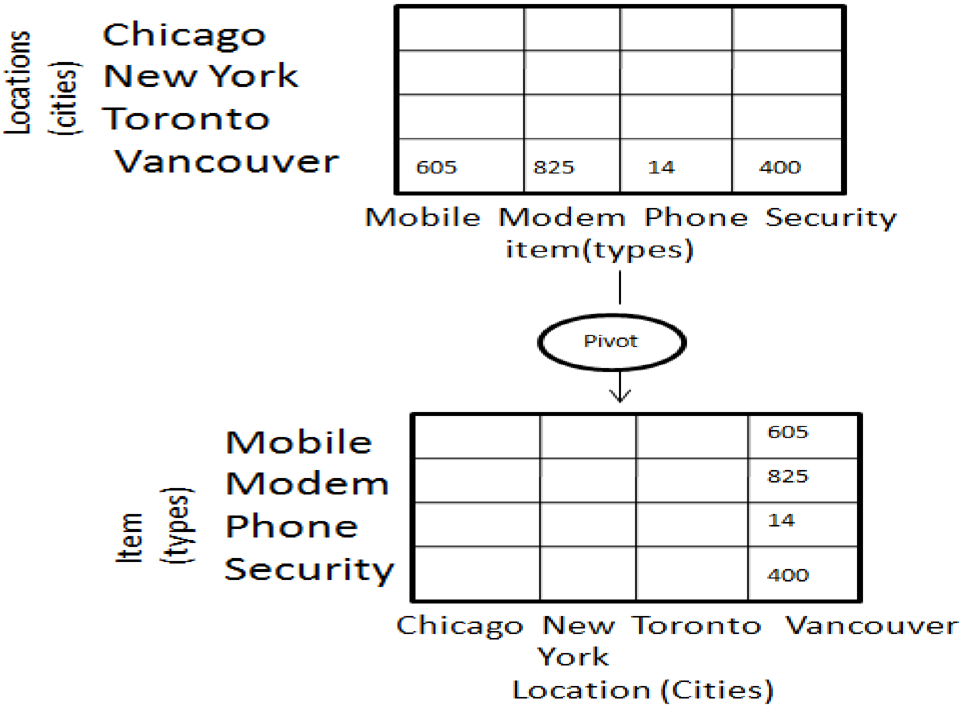


The dice operation on the cube based on the following selection criteria involves three dimensions.

- (location = "Toronto" or "Vancouver")
- (time = "Q1" or "Q2")
- (item =" Mobile" or "Modem")

Pivot

The pivot operation is also known as rotation. It rotates the data axes in view in order to provide an alternative presentation of data. Consider the following diagram that shows the pivot operation.



OLAP vs OLTP

Sr.No.	Data Warehouse (OLAP)	Operational Database (OLTP)
1	Involves historical processing of information.	Involves day-to-day processing.
2	OLAP systems are used by knowledge workers such as executives, managers and analysts.	OLTP systems are used by clerks, DBAs, or database professionals.
3	Useful in analyzing the business.	Useful in running the business.

4	It focuses on Information out.	It focuses on Data in.
5	Based on Star Schema, Snowflake, Schema and Fact Constellation Schema.	Based on Entity Relationship Model.
6	Contains historical data.	Contains current data.
7	Provides summarized and consolidated data.	Provides primitive and highly detailed data.
8	Provides summarized and multidimensional view of data.	Provides detailed and flat relational view of data.
9	Number or users is in hundreds.	Number of users is in thousands.
10	Number of records accessed is in millions.	Number of records accessed is in tens.
11	Database size is from 100 GB to 1 TB	Database size is from 100 MB to 1 GB.
12	Highly flexible.	Provides high performance.

Data Warehousing - Relational OLAP

Relational OLAP servers are placed between relational back-end server and client front-end tools. To store and manage the warehouse data, the relational OLAP uses relational or extended-relational DBMS.

ROLAP includes the following −

- Implementation of aggregation navigation logic
- Optimization for each DBMS back-end
- Additional tools and services

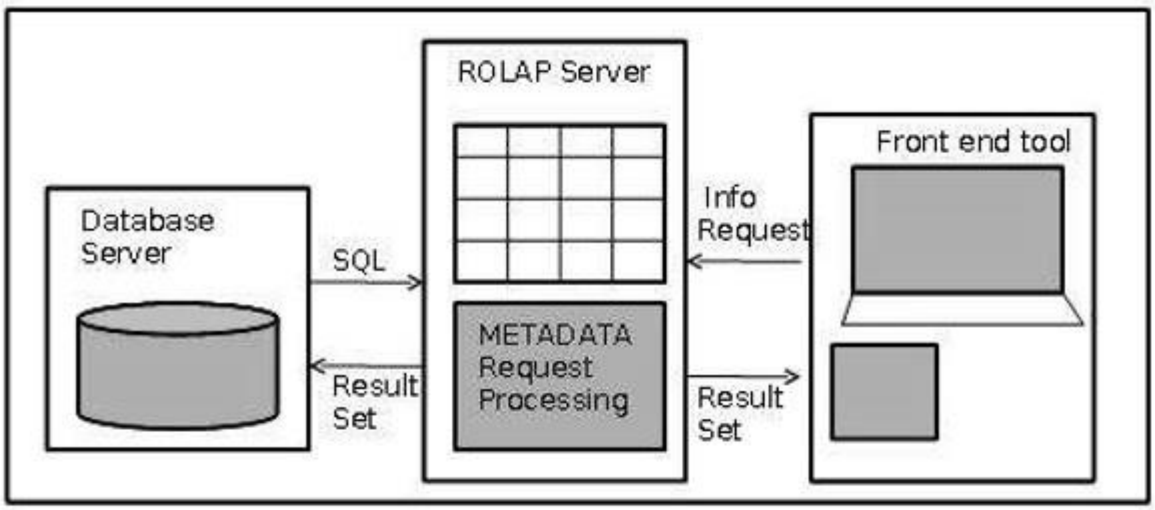
Points to Remember

- ROLAP servers are highly scalable.
- ROLAP tools analyze large volumes of data across multiple dimensions.
- ROLAP tools store and analyze highly volatile and changeable data.

Relational OLAP Architecture

ROLAP includes the following components −

- Database server
- ROLAP server
- Front-end tool.



Advantages

- ROLAP servers can be easily used with existing RDBMS.
- Data can be stored efficiently, since no zero facts can be stored.
- ROLAP tools do not use pre-calculated data cubes.
- DSS server of micro-strategy adopts the ROLAP approach.

Disadvantages

- Poor query performance.
- Some limitations of scalability depending on the technology architecture that is utilized.

Data Warehousing - Multidimensional OLAP

Multidimensional OLAP (MOLAP) uses array-based multidimensional storage engines for multidimensional views of data. With multidimensional data stores, the storage utilization may be low if the dataset is sparse. Therefore, many MOLAP servers use two levels of data storage representation to handle dense and sparse datasets.

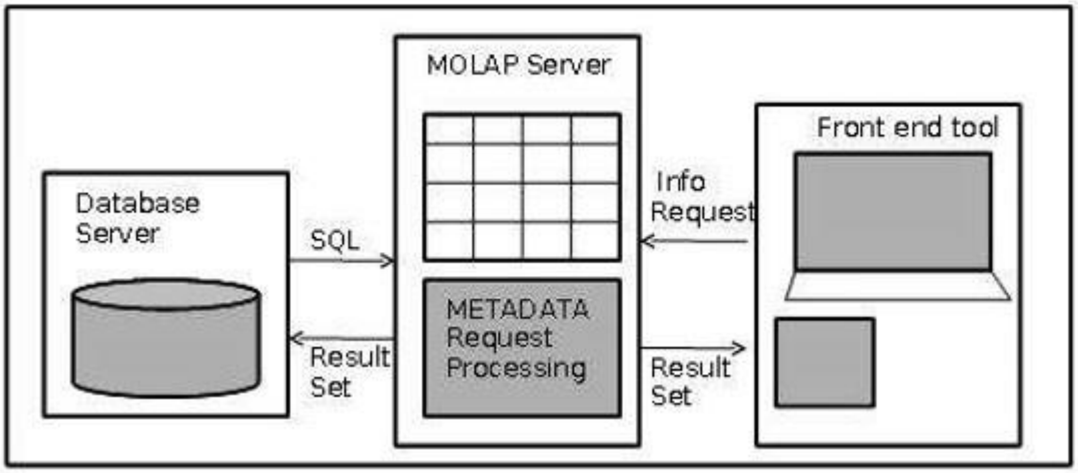
Points to Remember −

- MOLAP tools process information with consistent response time regardless of level of summarizing or calculations selected.
- MOLAP tools need to avoid many of the complexities of creating a relational database to store data for analysis.
- MOLAP tools need fastest possible performance.
- MOLAP server adopts two level of storage representation to handle dense and sparse data sets.
- Denser sub-cubes are identified and stored as array structure.
- Sparse sub-cubes employ compression technology.

MOLAP Architecture

MOLAP includes the following components −

- Database server.
- MOLAP server.
- Front-end tool.



Advantages

- MOLAP allows fastest indexing to the pre-computed summarized data.
- Helps the users connected to a network who need to analyze larger, less-defined data.
- Easier to use, therefore MOLAP is suitable for inexperienced users.

Disadvantages

- MOLAP are not capable of containing detailed data.
- The storage utilization may be low if the data set is sparse.

MOLAP vs ROLAP

Sr.No.	MOLAP	ROLAP
1	Information retrieval is fast.	Information retrieval is comparatively slow.
2	Uses sparse array to store data-sets.	Uses relational table.
3	MOLAP is best suited for inexperienced users, since it is very easy to use.	ROLAP is best suited for experienced users.

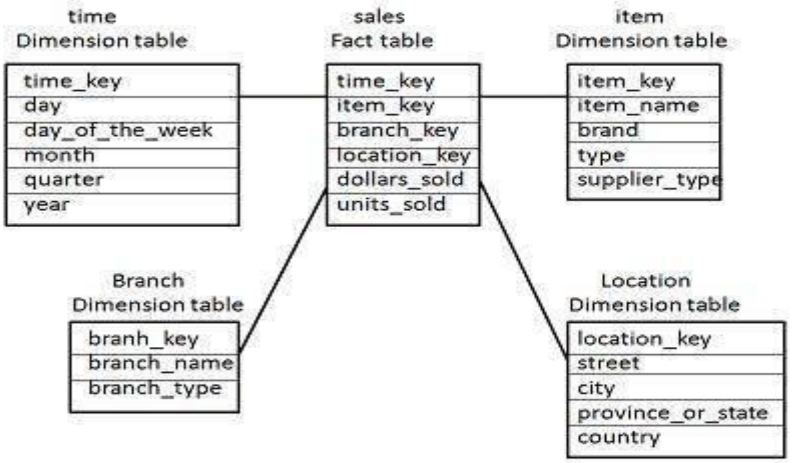
4	Maintains a separate database for data cubes.	It may not require space other than available in the Data warehouse.
5	DBMS facility is weak.	DBMS facility is strong.

Data Warehousing - Schemas

Schema is a logical description of the entire database. It includes the name and description of records of all record types including all associated data-items and aggregates. Much like a database, a data warehouse also requires to maintain a schema. A database uses relational model, while a data warehouse uses Star, Snowflake, and Fact Constellation schema. In this chapter, we will discuss the schemas used in a data warehouse.

Star Schema

- Each dimension in a star schema is represented with only one-dimension table.
- This dimension table contains the set of attributes.
- The following diagram shows the sales data of a company with respect to the four dimensions, namely time, item, branch, and location.

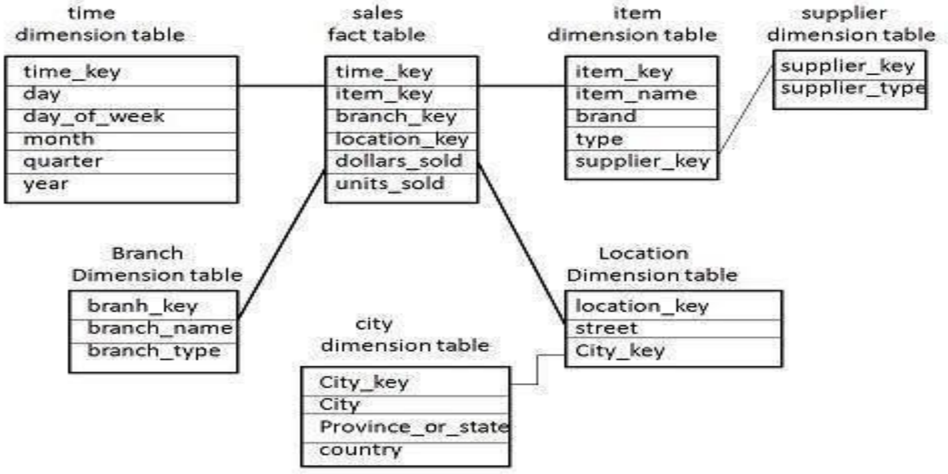


- There is a fact table at the center. It contains the keys to each of four dimensions.
- The fact table also contains the attributes, namely dollars sold and units sold.

Note − Each dimension has only one dimension table and each table holds a set of attributes. For example, the location dimension table contains the attribute set {location_key, street, city, province_or_state,country}. This constraint may cause data redundancy. For example, "Vancouver" and "Victoria" both the cities are in the Canadian province of British Columbia. The entries for such cities may cause data redundancy along the attributes province_or_state and country.

Snowflake Schema

- Some dimension tables in the Snowflake schema are normalized.
- The normalization splits up the data into additional tables.
- Unlike Star schema, the dimensions table in a snowflake schema are normalized. For example, the item dimension table in star schema is normalized and split into two dimension tables, namely item and supplier table.

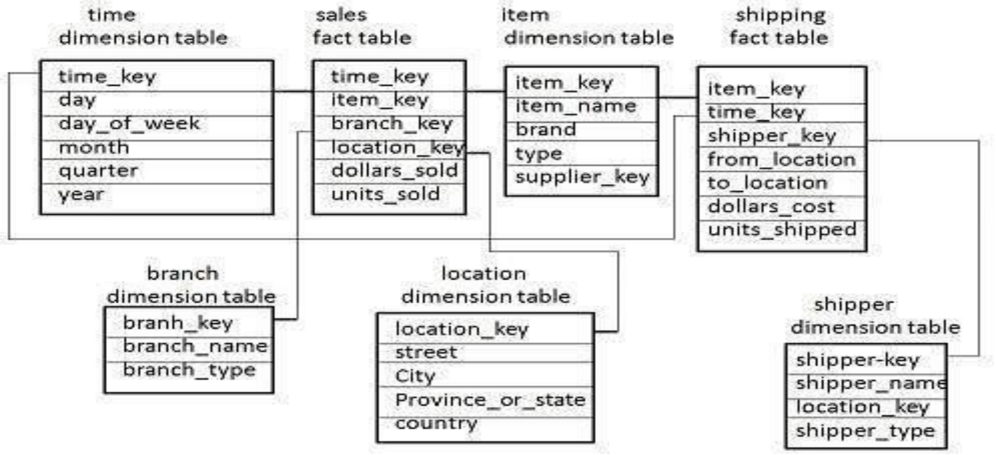


- Now the item dimension table contains the attributes item_key, item_name, type, brand, and supplier-key.
- The supplier key is linked to the supplier dimension table. The supplier dimension table contains the attributes supplier_key and supplier_type.

Note − Due to normalization in the Snowflake schema, the redundancy is reduced and therefore, it becomes easy to maintain and the save storage space.

Fact Constellation Schema

- A fact constellation has multiple fact tables. It is also known as galaxy schema.
- The following diagram shows two fact tables, namely sales and shipping.



- The sales fact table is same as that in the star schema.
- The shipping fact table has the five dimensions, namely item_key, time_key, shipper_key, from_location, to_location.
- The shipping fact table also contains two measures, namely dollars sold and units sold.
- It is also possible to share dimension tables between fact tables. For example, time, item, and location dimension tables are shared between the sales and shipping fact table.

Schema Definition

Multidimensional schema is defined using Data Mining Query Language (DMQL). The two primitives, cube definition and dimension definition, can be used for defining the data warehouses and data marts.

Syntax for Cube Definition

```
define cube < cube_name > [ < dimension-list > }: < measure_list >
```

Syntax for Dimension Definition

```
define dimension < dimension_name > as ( < attribute_or_dimension_list > )
```

Star Schema Definition

The star schema that we have discussed can be defined using Data Mining Query Language (DMQL) as follows −

```
define cube sales star [time, item, branch, location]:

dollars sold = sum(sales in dollars), units sold = count(*)

define dimension time as (time key, day, day of week, month, quarter, year)
define dimension item as (item key, item name, brand, type, supplier type)
define dimension branch as (branch key, branch name, branch type)
define dimension location as (location key, street, city, province or state, country)
```

Snowflake Schema Definition

Snowflake schema can be defined using DMQL as follows −

```
define cube sales snowflake [time, item, branch, location]:

dollars sold = sum(sales in dollars), units sold = count(*)

define dimension time as (time key, day, day of week, month, quarter, year)
define dimension item as (item key, item name, brand, type, supplier (supplier key, supplier
type))
define dimension branch as (branch key, branch name, branch type)
define dimension location as (location key, street, city (city key, city, province or state, country))
```

Fact Constellation Schema Definition

Fact constellation schema can be defined using DMQL as follows −

```
define cube sales [time, item, branch, location]:

dollars sold = sum(sales in dollars), units sold = count(*)

define dimension time as (time key, day, day of week, month, quarter, year)
define dimension item as (item key, item name, brand, type, supplier type)
define dimension branch as (branch key, branch name, branch type)
define dimension location as (location key, street, city, province or state,country)
define cube shipping [time, item, shipper, from location, to location]:

dollars cost = sum(cost in dollars), units shipped = count(*)

define dimension time as time in cube sales
define dimension item as item in cube sales
define dimension shipper as (shipper key, shipper name, location as location in cube sales, shipper type)
define dimension from location as location in cube sales
define dimension to location as location in cube sales
```

Data Warehousing - Partitioning Strategy

Partitioning is done to enhance performance and facilitate easy management of data. Partitioning also helps in balancing the various requirements of the system. It optimizes the hardware performance and simplifies the management of data warehouse by partitioning each fact table into multiple separate partitions. In this chapter, we will discuss different partitioning strategies.

Why is it Necessary to Partition?

Partitioning is important for the following reasons −

- For easy management,
- To assist backup/recovery,
- To enhance performance.

For Easy Management

The fact table in a data warehouse can grow up to hundreds of gigabytes in size. This huge size of fact table is very hard to manage as a single entity. Therefore it needs partitioning.

To Assist Backup/Recovery

If we do not partition the fact table, then we have to load the complete fact table with all the data. Partitioning allows us to load only as much data as is required on a regular basis. It reduces the time to load and also enhances the performance of the system.

Note − To cut down on the backup size, all partitions other than the current partition can be marked as read-only. We can then put these partitions into a state where they cannot be modified. Then they can be backed up. It means only the current partition is to be backed up.

To Enhance Performance

By partitioning the fact table into sets of data, the query procedures can be enhanced. Query performance is enhanced because now the query scans only those partitions that are relevant. It does not have to scan the whole data.

Horizontal Partitioning

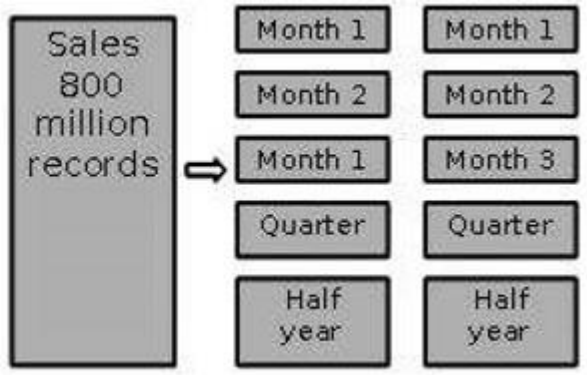
There are various ways in which a fact table can be partitioned. In horizontal partitioning, we have to keep in mind the requirements for manageability of the data warehouse.

Partitioning by Time into Equal Segments

In this partitioning strategy, the fact table is partitioned on the basis of time period. Here each time period represents a significant retention period within the business. For example, if the user queries for **month to date data** then it is appropriate to partition the data into monthly segments. We can reuse the partitioned tables by removing the data in them.

Partition by Time into Different-sized Segments

This kind of partition is done where the aged data is accessed infrequently. It is implemented as a set of small partitions for relatively current data, larger partition for inactive data.



Points to Note

- The detailed information remains available online.
- The number of physical tables is kept relatively small, which reduces the operating cost.
- This technique is suitable where a mix of data dipping recent history and data mining through entire history is required.
- This technique is not useful where the partitioning profile changes on a regular basis, because repartitioning will increase the operation cost of data warehouse.

Partition on a Different Dimension

The fact table can also be partitioned on the basis of dimensions other than time such as product group, region, supplier, or any other dimension. Let's have an example.

Suppose a market function has been structured into distinct regional departments like on a **state by state** basis. If each region wants to query on information captured within its region, it would prove to be more effective to partition the fact table into regional partitions. This will cause the queries to speed up because it does not require to scan information that is not relevant.

Points to Note

- The query does not have to scan irrelevant data which speeds up the query process.
- This technique is not appropriate where the dimensions are unlikely to change in future. So, it is worth determining that the dimension does not change in future.
- If the dimension changes, then the entire fact table would have to be repartitioned.

Note − We recommend to perform the partition only on the basis of time dimension, unless you are certain that the suggested dimension grouping will not change within the life of the data warehouse.

Partition by Size of Table

When there are no clear basis for partitioning the fact table on any dimension, then we should **partition the fact table on the basis of their size.** We can set the predetermined size as a critical point. When the table exceeds the predetermined size, a new table partition is created.

Points to Note

- This partitioning is complex to manage.
- It requires metadata to identify what data is stored in each partition.

Partitioning Dimensions

If a dimension contains large number of entries, then it is required to partition the dimensions. Here we have to check the size of a dimension.

Consider a large design that changes over time. If we need to store all the variations in order to apply comparisons, that dimension may be very large. This would definitely affect the response time.

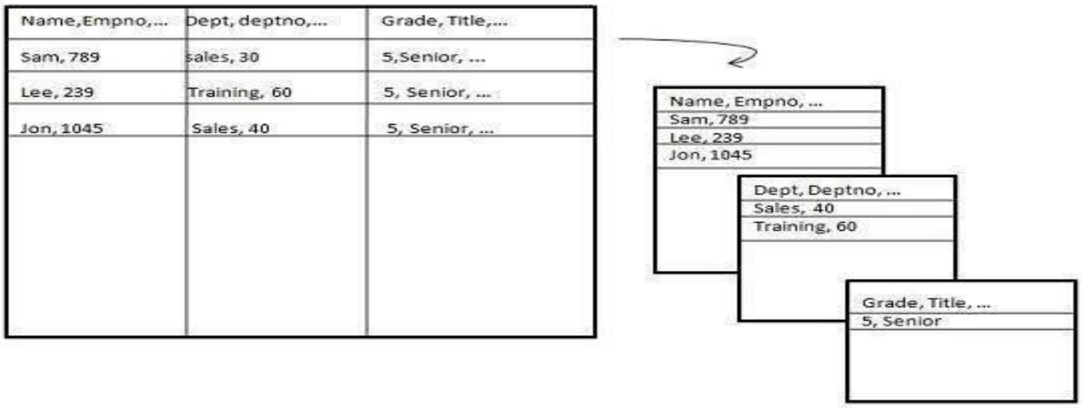
Round Robin Partitions

In the round robin technique, when a new partition is needed, the old one is archived. It uses metadata to allow user access tool to refer to the correct table partition.

This technique makes it easy to automate table management facilities within the data warehouse.

Vertical Partition

Vertical partitioning, splits the data vertically. The following images depicts how vertical partitioning is done.



Name,Empno,...	Dept, deptno,...	Grade, Title,...
Sam, 789	Sales, 30	5,Senior, ...
Lee, 239	Training, 60	5, Senior, ...
Jon, 1045	Sales, 40	5, Senior, ...

Name, Empno, ...
Sam, 789
Lee, 239
Jon, 1045

Dept, Deptno, ...
Sales, 40
Training, 60

Grade, Title, ...
5, Senior

Vertical partitioning can be performed in the following two ways −

- Normalization
- Row Splitting

Normalization

Normalization is the standard relational method of database organization. In this method, the rows are collapsed into a single row, hence it reduce space. Take a look at the following tables that show how normalization is performed.

Table before Normalization

Product_id	Qty	Value	sales_date	Store_id	Store_name	Location	Region
30	5	3.67	3-Aug-13	16	sunny	Bangalore	S

35	4	5.33	3-Sep-13	16	sunny	Bangalore	S
40	5	2.50	3-Sep-13	64	san	Mumbai	W
45	7	5.66	3-Sep-13	16	sunny	Bangalore	S

Table after Normalization

Store_id	**Store_name**	**Location**	**Region**
16	sunny	Bangalore	W
64	san	Mumbai	S

Product_id	**Quantity**	**Value**	**sales_date**	**Store_id**
30	5	3.67	3-Aug-13	16
35	4	5.33	3-Sep-13	16
40	5	2.50	3-Sep-13	64
45	7	5.66	3-Sep-13	16

Row Splitting

Row splitting tends to leave a one-to-one map between partitions. The motive of row splitting is to speed up the access to large table by reducing its size.

Note − While using vertical partitioning, make sure that there is no requirement to perform a major join operation between two partitions.

Identify Key to Partition

It is very crucial to choose the right partition key. Choosing a wrong partition key will lead to reorganizing the fact table. Let's have an example. Suppose we want to partition the following table.

Account_Txn_Table
transaction_id
account_id
transaction_type
value
transaction_date
region
branch_name

We can choose to partition on any key. The two possible keys could be

- region
- transaction_date

Suppose the business is organized in 30 geographical regions and each region has different number of branches. That will give us 30 partitions, which is reasonable. This partitioning is good enough because our requirements capture has shown that a vast majority of queries are restricted to the user's own business region.

If we partition by transaction_date instead of region, then the latest transaction from every region will be in one partition. Now the user who wants to look at data within his own region has to query across multiple partitions.

Hence it is worth determining the right partitioning key.

Data Warehousing - Metadata Concepts

What is Metadata?

Metadata is simply defined as data about data. The data that is used to represent other data is known as metadata. For example, the index of a book serves as a metadata for the contents in the book. In other words, we can say that metadata is the summarized data that leads us to detailed data. In terms of data warehouse, we can define metadata as follows.

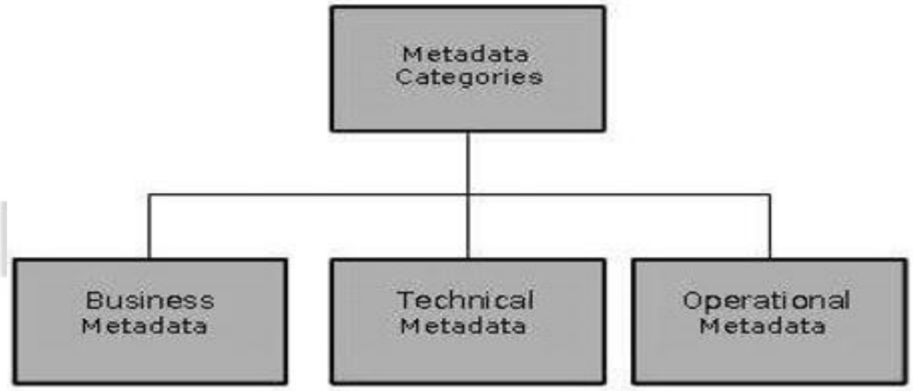
- Metadata is the road-map to a data warehouse.
- Metadata in a data warehouse defines the warehouse objects.
- Metadata acts as a directory. This directory helps the decision support system to locate the contents of a data warehouse.

Note − In a data warehouse, we create metadata for the data names and definitions of a given data warehouse. Along with this metadata, additional metadata is also created for time-stamping any extracted data, the source of extracted data.

Categories of Metadata

Metadata can be broadly categorized into three categories −

- **Business Metadata** − It has the data ownership information, business definition, and changing policies.
- **Technical Metadata** − It includes database system names, table and column names and sizes, data types and allowed values. Technical metadata also includes structural information such as primary and foreign key attributes and indices.
- **Operational Metadata** − It includes currency of data and data lineage. Currency of data means whether the data is active, archived, or purged. Lineage of data means the history of data migrated and transformation applied on it.

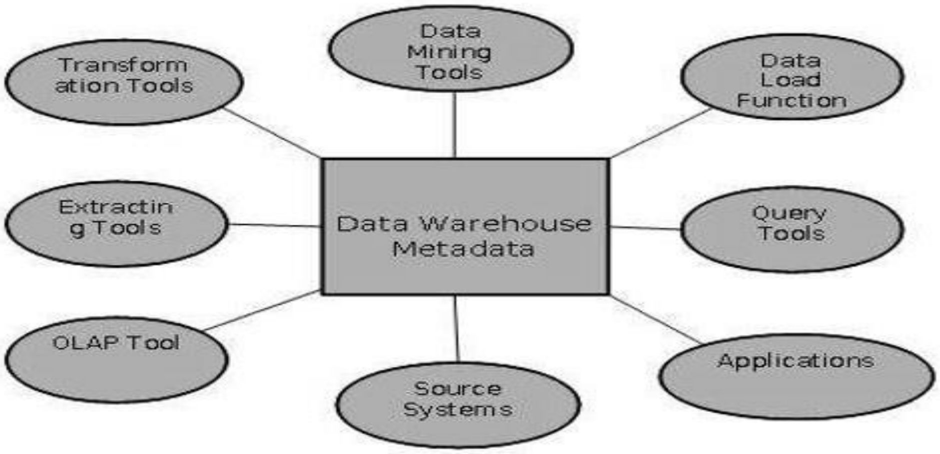


Role of Metadata

Metadata has a very important role in a data warehouse. The role of metadata in a warehouse is different from the warehouse data, yet it plays an important role. The various roles of metadata are explained below.

- Metadata acts as a directory.
- This directory helps the decision support system to locate the contents of the data warehouse.
- Metadata helps in decision support system for mapping of data when data is transformed from operational environment to data warehouse environment.
- Metadata helps in summarization between current detailed data and highly summarized data.
- Metadata also helps in summarization between lightly detailed data and highly summarized data.
- Metadata is used for query tools.
- Metadata is used in extraction and cleansing tools.
- Metadata is used in reporting tools.
- Metadata is used in transformation tools.
- Metadata plays an important role in loading functions.

The following diagram shows the roles of metadata.



Metadata Repository

Metadata repository is an integral part of a data warehouse system. It has the following metadata −

- **Definition of data warehouse** − It includes the description of structure of data warehouse. The description is defined by schema, view, hierarchies, derived data definitions, and data mart locations and contents.
- **Business metadata** − It contains has the data ownership information, business definition, and changing policies.
- **Operational Metadata** − It includes currency of data and data lineage. Currency of data means whether the data is active, archived, or purged. Lineage of data means the history of data migrated and transformation applied on it.
- **Data for mapping from operational environment to data warehouse** − It includes the source databases and their contents, data extraction, data partition cleaning, transformation rules, data refresh and purging rules.
- **Algorithms for summarization** − It includes dimension algorithms, data on granularity, aggregation, summarizing, etc.

Challenges for Metadata Management

The importance of metadata can not be overstated. Metadata helps in driving the accuracy of reports, validates data transformation, and ensures the accuracy of calculations. Metadata also enforces the definition of business terms to business end-users. With all these uses of metadata, it also has its challenges. Some of the challenges are discussed below.

- Metadata in a big organization is scattered across the organization. This metadata is spread in spreadsheets, databases, and applications.
- Metadata could be present in text files or multimedia files. To use this data for information management solutions, it has to be correctly defined.
- There are no industry-wide accepted standards. Data management solution vendors have narrow focus.
- There are no easy and accepted methods of passing metadata.

Data Warehousing - Data Marting

Why Do We Need a Data Mart?

Listed below are the reasons to create a data mart −

- To partition data in order to impose **access control strategies.**
- To speed up the queries by reducing the volume of data to be scanned.
- To segment data into different hardware platforms.
- To structure data in a form suitable for a user access tool.

Note − Do not data mart for any other reason since the operation cost of data marting could be very high. Before data marting, make sure that data marting strategy is appropriate for your particular solution.

Cost-effective Data Marting

Follow the steps given below to make data marting cost-effective −

- Identify the Functional Splits
- Identify User Access Tool Requirements
- Identify Access Control Issues

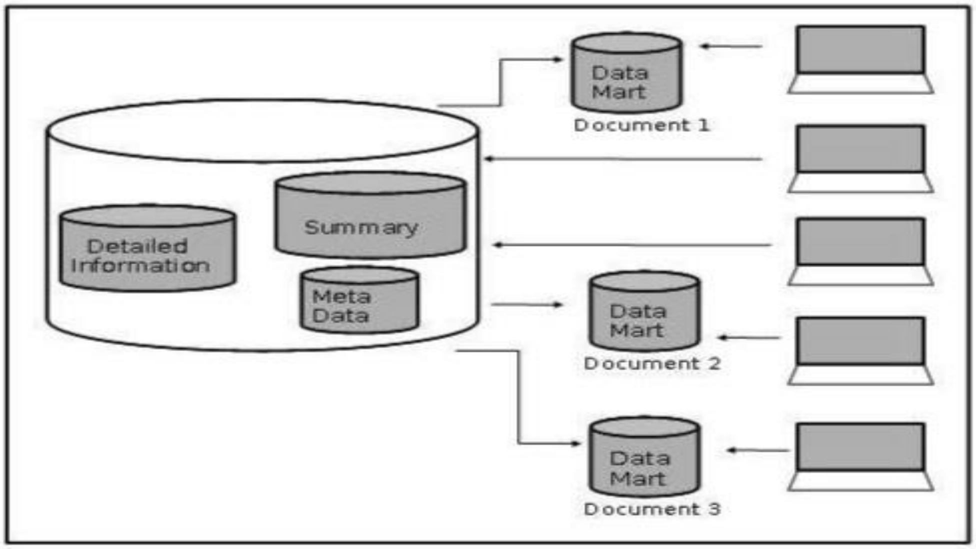
Identify the Functional Splits

In this step, we determine if the organization has natural functional splits. We look for departmental splits, and we determine whether the way in which departments use information tend to be in isolation from the rest of the organization. Let's have an example.

Consider a retail organization, where each merchant is accountable for maximizing the sales of a group of products. For this, the following are the valuable information −

- sales transaction on a daily basis
- sales forecast on a weekly basis
- stock position on a daily basis
- stock movements on a daily basis

As the merchant is not interested in the products they are not dealing with, the data marting is a subset of the data dealing which the product group of interest. The following diagram shows data marting for different users.



Given below are the issues to be taken into account while determining the functional split −

- The structure of the department may change.
- The products might switch from one department to other.

- The merchant could query the sales trend of other products to analyze what is happening to the sales.

Note − We need to determine the business benefits and technical feasibility of using a data mart.

Identify User Access Tool Requirements

We need data marts to support **user access tools** that require internal data structures. The data in such structures are outside the control of data warehouse but need to be populated and updated on a regular basis.

There are some tools that populate directly from the source system but some cannot. Therefore additional requirements outside the scope of the tool are needed to be identified for future.

Note − In order to ensure consistency of data across all access tools, the data should not be directly populated from the data warehouse, rather each tool must have its own data mart.

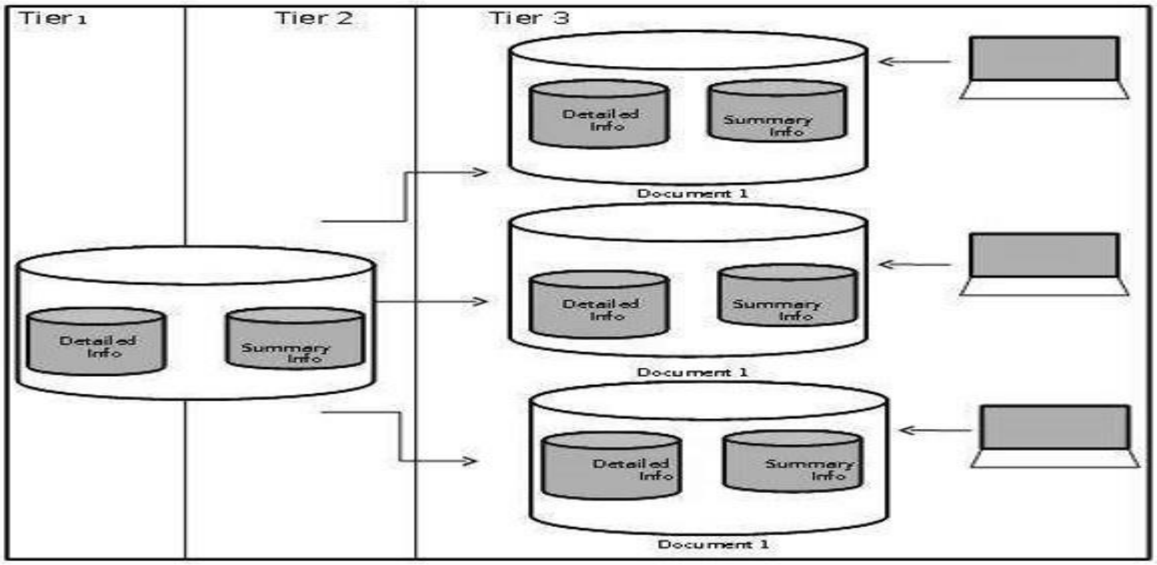
Identify Access Control Issues

There should to be privacy rules to ensure the data is accessed by authorized users only. For example a data warehouse for retail banking institution ensures that all the accounts belong to the same legal entity. Privacy laws can force you to totally prevent access to information that is not owned by the specific bank.

Data marts allow us to build a complete wall by physically separating data segments within the data warehouse. To avoid possible privacy problems, the detailed data can be removed from the data warehouse. We can create data mart for each legal entity and load it via data warehouse, with detailed account data.

Designing Data Marts

Data marts should be designed as a smaller version of starflake schema within the data warehouse and should match with the database design of the data warehouse. It helps in maintaining control over database instances.



The summaries are data marted in the same way as they would have been designed within the data warehouse. Summary tables help to utilize all dimension data in the starflake schema.

Cost of Data Marting

The cost measures for data marting are as follows −

- Hardware and Software Cost
- Network Access
- Time Window Constraints

Hardware and Software Cost

Although data marts are created on the same hardware, they require some additional hardware and software. To handle user queries, it requires additional processing power and disk storage. If detailed data and the data mart exist within the data warehouse, then we would face additional cost to store and manage replicated data.

Note − Data marting is more expensive than aggregations, therefore it should be used as an additional strategy and not as an alternative strategy.

Network Access

A data mart could be on a different location from the data warehouse, so we should ensure that the LAN or WAN has the capacity to handle the data volumes being transferred within the **data mart load process.**

Time Window Constraints

The extent to which a data mart loading process will eat into the available time window depends on the complexity of the transformations and the data volumes being shipped. The determination of how many data marts are possible depends on −

- Network capacity.
- Time window available
- Volume of data being transferred
- Mechanisms being used to insert data into a data mart

Data Warehousing - System Managers

System management is mandatory for the successful implementation of a data warehouse. The most important system managers are −

- System configuration manager
- System scheduling manager
- System event manager
- System database manager
- System backup recovery manager

System Configuration Manager

- The system configuration manager is responsible for the management of the setup and configuration of data warehouse.
- The structure of configuration manager varies from one operating system to another.
- In Unix structure of configuration, the manager varies from vendor to vendor.
- Configuration managers have single user interface.
- The interface of configuration manager allows us to control all aspects of the system.

Note − The most important configuration tool is the I/O manager.

System Scheduling Manager

System Scheduling Manager is responsible for the successful implementation of the data warehouse. Its purpose is to schedule ad hoc queries. Every operating system has its own scheduler with some form of batch control mechanism. The list of features a system scheduling manager must have is as follows −

- Work across cluster or MPP boundaries
- Deal with international time differences
- Handle job failure
- Handle multiple queries
- Support job priorities
- Restart or re-queue the failed jobs
- Notify the user or a process when job is completed
- Maintain the job schedules across system outages
- Re-queue jobs to other queues
- Support the stopping and starting of queues
- Log Queued jobs
- Deal with inter-queue processing

Note − The above list can be used as evaluation parameters for the evaluation of a good scheduler.

Some important jobs that a scheduler must be able to handle are as follows −

- Daily and ad hoc query scheduling
- Execution of regular report requirements
- Data load
- Data processing
- Index creation
- Backup
- Aggregation creation

- Data transformation

Note − If the data warehouse is running on a cluster or MPP architecture, then the system scheduling manager must be capable of running across the architecture.

System Event Manager

The event manager is a kind of a software. The event manager manages the events that are defined on the data warehouse system. We cannot manage the data warehouse manually because the structure of data warehouse is very complex. Therefore we need a tool that automatically handles all the events without any intervention of the user.

Note − The Event manager monitors the events occurrences and deals with them. The event manager also tracks the myriad of things that can go wrong on this complex data warehouse system.

Events

Events are the actions that are generated by the user or the system itself. It may be noted that the event is a measurable, observable, occurrence of a defined action.

Given below is a list of common events that are required to be tracked.

- Hardware failure
- Running out of space on certain key disks
- A process dying
- A process returning an error
- CPU usage exceeding an 805 threshold
- Internal contention on database serialization points
- Buffer cache hit ratios exceeding or failure below threshold
- A table reaching to maximum of its size
- Excessive memory swapping
- A table failing to extend due to lack of space
- Disk exhibiting I/O bottlenecks
- Usage of temporary or sort area reaching a certain thresholds
- Any other database shared memory usage

The most important thing about events is that they should be capable of executing on their own. Event packages define the procedures for the predefined events. The code associated with each event is known as event handler. This code is executed whenever an event occurs.

System and Database Manager

System and database manager may be two separate pieces of software, but they do the same job. The objective of these tools is to automate certain processes and to simplify the execution of others. The criteria for choosing a system and the database manager are as follows −

- increase user's quota.
- assign and de-assign roles to the users
- assign and de-assign the profiles to the users
- perform database space management
- monitor and report on space usage
- tidy up fragmented and unused space
- add and expand the space
- add and remove users
- manage user password
- manage summary or temporary tables
- assign or deassign temporary space to and from the user
- reclaim the space form old or out-of-date temporary tables
- manage error and trace logs
- to browse log and trace files
- redirect error or trace information
- switch on and off error and trace logging
- perform system space management
- monitor and report on space usage
- clean up old and unused file directories
- add or expand space.

System Backup Recovery Manager

The backup and recovery tool makes it easy for operations and management staff to back-up the data. Note that the system backup manager must be integrated with the schedule manager software being used. The important features that are required for the management of backups are as follows −

- Scheduling
- Backup data tracking
- Database awareness

Backups are taken only to protect against data loss. Following are the important points to remember −

- The backup software will keep some form of database of where and when the piece of data was backed up.
- The backup recovery manager must have a good front-end to that database.
- The backup recovery software should be database aware.
- Being aware of the database, the software then can be addressed in database terms, and will not perform backups that would not be viable.

Data Warehousing - Process Managers

Process managers are responsible for maintaining the flow of data both into and out of the data warehouse. There are three different types of process managers −

- Load manager
- Warehouse manager
- Query manager

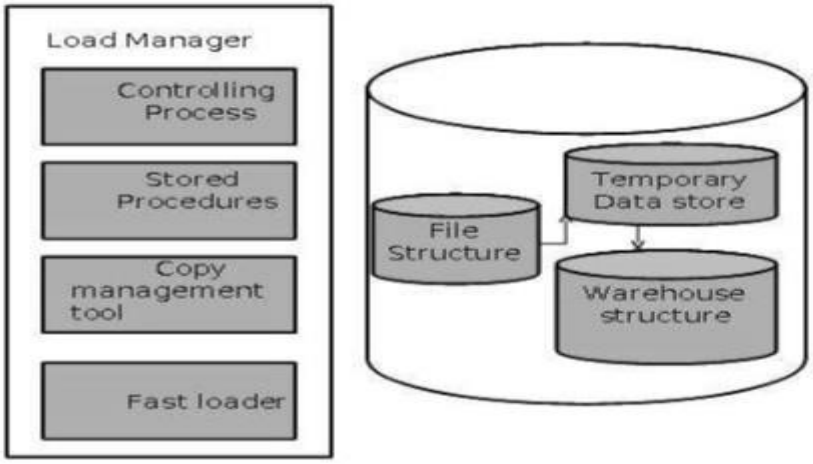
Data Warehouse Load Manager

Load manager performs the operations required to extract and load the data into the database. The size and complexity of a load manager varies between specific solutions from one data warehouse to another.

Load Manager Architecture

The load manager does performs the following functions –

- Extract data from the source system.
- Fast load the extracted data into temporary data store.
- Perform simple transformations into structure similar to the one in the data warehouse.



Extract Data from Source

The data is extracted from the operational databases or the external information providers. Gateways are the application programs that are used to extract data. It is supported by underlying DBMS and allows the client program to generate SQL to be executed at a server. Open Database Connection (ODBC) and Java Database Connection (JDBC) are examples of gateway.

Fast Load

- In order to minimize the total load window, the data needs to be loaded into the warehouse in the fastest possible time.
- Transformations affect the speed of data processing.
- It is more effective to load the data into a relational database prior to applying transformations and checks.
- Gateway technology is not suitable, since they are inefficient when large data volumes are involved.

Simple Transformations

While loading, it may be required to perform simple transformations. After completing simple transformations, we can do complex checks. Suppose we are loading the EPOS sales transaction, we need to perform the following checks −

- Strip out all the columns that are not required within the warehouse.
- Convert all the values to required data types.

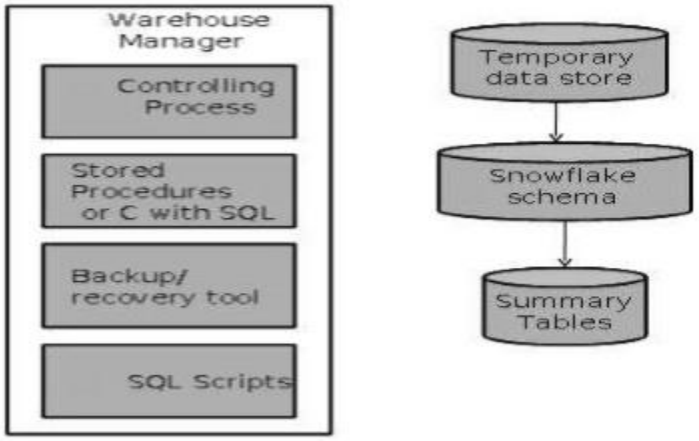
Warehouse Manager

The warehouse manager is responsible for the warehouse management process. It consists of a third-party system software, C programs, and shell scripts. The size and complexity of a warehouse manager varies between specific solutions.

Warehouse Manager Architecture

A warehouse manager includes the following −

- The controlling process
- Stored procedures or C with SQL
- Backup/Recovery tool
- SQL scripts



Functions of Warehouse Manager

A warehouse manager performs the following functions −

- Analyzes the data to perform consistency and referential integrity checks.

- Creates indexes, business views, partition views against the base data.
- Generates new aggregations and updates the existing aggregations.
- Generates normalizations.
- Transforms and merges the source data of the temporary store into the published data warehouse.
- Backs up the data in the data warehouse.
- Archives the data that has reached the end of its captured life.

Note − A warehouse Manager analyzes query profiles to determine whether the index and aggregations are appropriate.

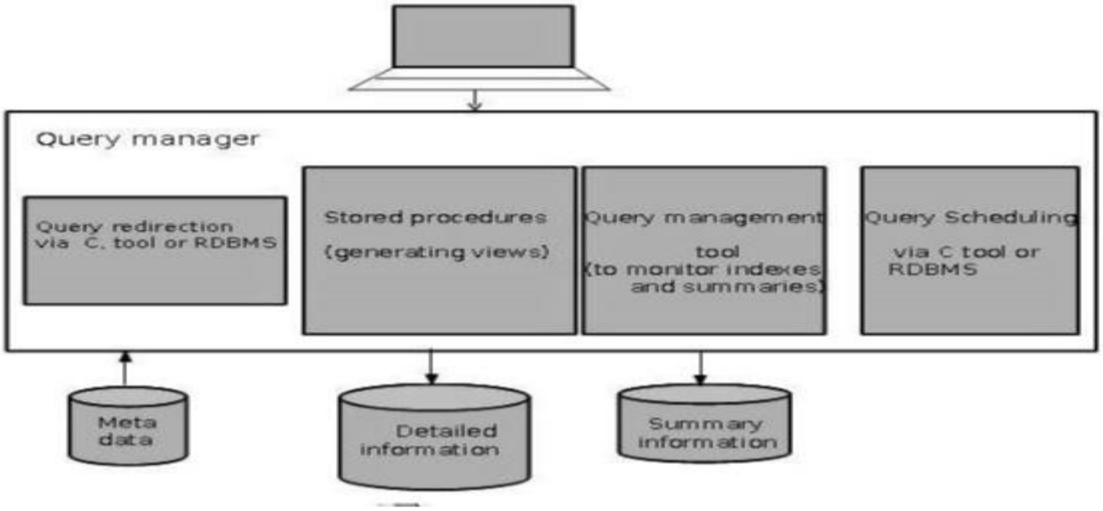
Query Manager

The query manager is responsible for directing the queries to suitable tables. By directing the queries to appropriate tables, it speeds up the query request and response process. In addition, the query manager is responsible for scheduling the execution of the queries posted by the user.

Query Manager Architecture

A query manager includes the following components −

- Query redirection via C tool or RDBMS
- Stored procedures
- Query management tool
- Query scheduling via C tool or RDBMS
- Query scheduling via third-party software


Query manager
Query redirection via C tool or RDBMS
Stored procedures (generating views)
Query management tool (to monitor indexes and summaries)
Query Scheduling via C tool or RDBMS
Meta data
Detailed information
Summary information

Functions of Query Manager

- It presents the data to the user in a form they understand.
- It schedules the execution of the queries posted by the end-user.
- It stores query profiles to allow the warehouse manager to determine which indexes and aggregations are appropriate.

Data Warehousing - Security

The objective of a data warehouse is to make large amounts of data easily accessible to the users, hence allowing the users to extract information about the business as a whole. But we know that there could be some security restrictions applied on the data that can be an obstacle for accessing the information. If the analyst has a restricted view of data, then it is impossible to capture a complete picture of the trends within the business.

The data from each analyst can be summarized and passed on to management where the different summaries can be aggregated. As the aggregations of summaries cannot be the same as that of the aggregation as a whole, it is possible to miss some information trends in the data unless someone is analyzing the data as a whole.

Security Requirements

Adding security features affect the performance of the data warehouse, therefore it is important to determine the security requirements as early as possible. It is difficult to add security features after the data warehouse has gone live.

During the design phase of the data warehouse, we should keep in mind what data sources may be added later and what would be the impact of adding those data sources. We should consider the following possibilities during the design phase.

- Whether the new data sources will require new security and/or audit restrictions to be implemented?
- Whether the new users added who have restricted access to data that is already generally available?

This situation arises when the future users and the data sources are not well known. In such a situation, we need to use the knowledge of business and the objective of data warehouse to know likely requirements.

The following activities get affected by security measures −

- User access
- Data load
- Data movement
- Query generation

User Access

We need to first classify the data and then classify the users on the basis of the data they can access. In other words, the users are classified according to the data they can access.

Data Classification

The following two approaches can be used to classify the data −

- Data can be classified according to its sensitivity. Highly-sensitive data is classified as highly restricted and less-sensitive data is classified as less restrictive.
- Data can also be classified according to the job function. This restriction allows only specific users to view particular data. Here we restrict the users to view only that part of the data in which they are interested and are responsible for.

There are some issues in the second approach. To understand, let's have an example. Suppose you are building the data warehouse for a bank. Consider that the data being stored in the data warehouse is the transaction data for all the accounts. The question here is, who is allowed to see the transaction data. The solution lies in classifying the data according to the function.

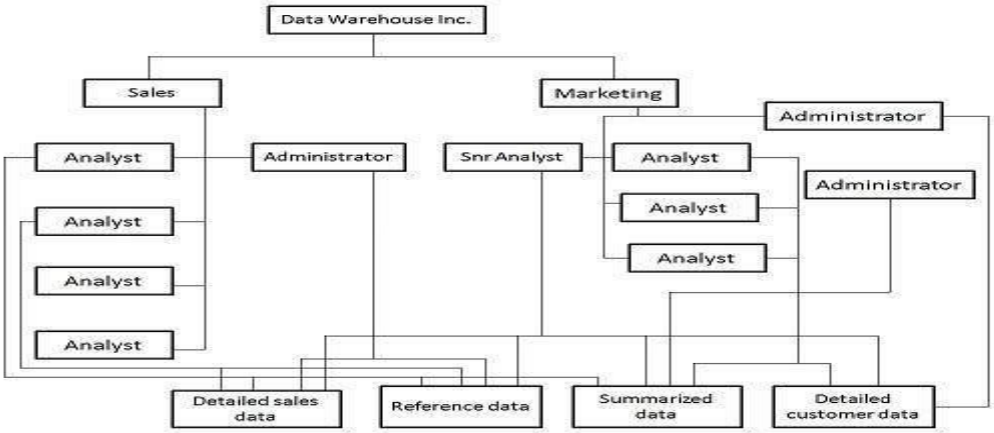
User classification

The following approaches can be used to classify the users −

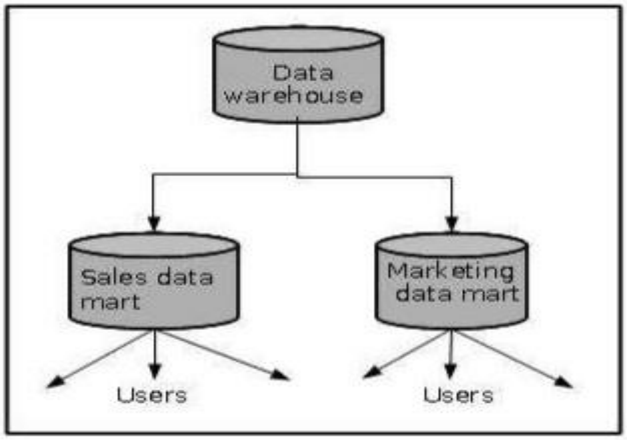
- Users can be classified as per the hierarchy of users in an organization, i.e., users can be classified by departments, sections, groups, and so on.
- Users can also be classified according to their role, with people grouped across departments based on their role.

Classification on basis of Department

Let's have an example of a data warehouse where the users are from sales and marketing department. We can have security by top-to-down company view, with access centered on the different departments. But there could be some restrictions on users at different levels. This structure is shown in the following diagram.

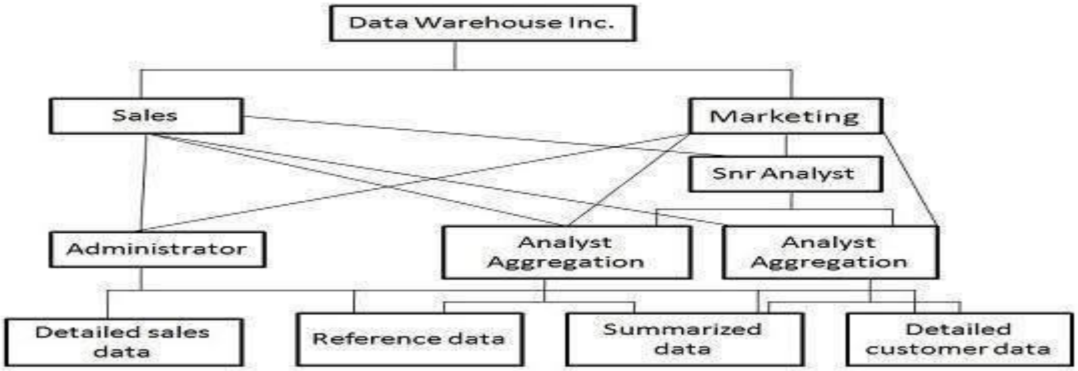


But if each department accesses different data, then we should design the security access for each department separately. This can be achieved by departmental data marts. Since these data marts are separated from the data warehouse, we can enforce separate security restrictions on each data mart. This approach is shown in the following figure.



Classification Based on Role

If the data is generally available to all the departments, then it is useful to follow the role access hierarchy. In other words, if the data is generally accessed by all the departments, then apply security restrictions as per the role of the user. The role access hierarchy is shown in the following figure.



Audit Requirements

Auditing is a subset of security, a costly activity. Auditing can cause heavy overheads on the system. To complete an audit in time, we require more hardware and therefore, it is recommended that wherever possible, auditing should be switched off. Audit requirements can be categorized as follows −

- Connections
- Disconnections

- Data access
- Data change

Note − For each of the above-mentioned categories, it is necessary to audit success, failure, or both. From the perspective of security reasons, the auditing of failures are very important. Auditing of failure is important because they can highlight unauthorized or fraudulent access.

Network Requirements

Network security is as important as other securities. We cannot ignore the network security requirement. We need to consider the following issues −

- Is it necessary to encrypt data before transferring it to the data warehouse?
- Are there restrictions on which network routes the data can take?

These restrictions need to be considered carefully. Following are the points to remember −

- The process of encryption and decryption will increase overheads. It would require more processing power and processing time.
- The cost of encryption can be high if the system is already a loaded system because the encryption is borne by the source system.

Data Movement

There exist potential security implications while moving the data. Suppose we need to transfer some restricted data as a flat file to be loaded. When the data is loaded into the data warehouse, the following questions are raised −

- Where is the flat file stored?
- Who has access to that disk space?

If we talk about the backup of these flat files, the following questions are raised −

- Do you backup encrypted or decrypted versions?
- Do these backups need to be made to special tapes that are stored separately?
- Who has access to these tapes?

Some other forms of data movement like query result sets also need to be considered. The questions raised while creating the temporary table are as follows −

- Where is that temporary table to be held?
- How do you make such table visible?

We should avoid the accidental flouting of security restrictions. If a user with access to the restricted data can generate accessible temporary tables, data can be visible to non-authorized users. We can overcome this problem by having a separate temporary area for users with access to restricted data.

Documentation

The audit and security requirements need to be properly documented. This will be treated as a part of justification. This document can contain all the information gathered from −

- Data classification
- User classification
- Network requirements
- Data movement and storage requirements
- All auditable actions

Impact of Security on Design

Security affects the application code and the development timescales. Security affects the following area −

- Application development
- Database design
- Testing

Application Development

Security affects the overall application development and it also affects the design of the important components of the data warehouse such as load manager, warehouse manager, and query manager. The load manager may require checking code to filter record and place them in different locations. More transformation rules may also be required to hide certain data. Also there may be requirements of extra metadata to handle any extra objects.

To create and maintain extra views, the warehouse manager may require extra codes to enforce security. Extra checks may have to be coded into the data warehouse to prevent it from being fooled into moving data into a location where it should not be available. The query manager requires the changes to handle any access restrictions. The query manager will need to be aware of all extra views and aggregations.

Database design

The database layout is also affected because when security measures are implemented, there is an increase in the number of views and tables. Adding security increases the size of the database and hence increases the complexity of the database design and management. It will also add complexity to the backup management and recovery plan.

Testing

Testing the data warehouse is a complex and lengthy process. Adding security to the data warehouse also affects the testing time complexity. It affects the testing in the following two ways −

- It will increase the time required for integration and system testing.
- There is added functionality to be tested which will increase the size of the testing suite.

Data Warehousing - Backup

A data warehouse is a complex system and it contains a huge volume of data. Therefore it is important to back up all the data so that it becomes available for recovery in future as per requirement. In this chapter, we will discuss the issues in designing the backup strategy.

Backup Terminologies

Before proceeding further, you should know some of the backup terminologies discussed below.

- **Complete backup** − It backs up the entire database at the same time. This backup includes all the database files, control files, and journal files.
- **Partial backup** − As the name suggests, it does not create a complete backup of the database. Partial backup is very useful in large databases because they allow a strategy whereby various parts of the database are backed up in a round-robin fashion on a day-to-day basis, so that the whole database is backed up effectively once a week.
- **Cold backup** − Cold backup is taken while the database is completely shut down. In multi-instance environment, all the instances should be shut down.

- **Hot backup** − Hot backup is taken when the database engine is up and running. The requirements of hot backup varies from RDBMS to RDBMS.
- **Online backup** − It is quite similar to hot backup.

Hardware Backup

It is important to decide which hardware to use for the backup. The speed of processing the backup and restore depends on the hardware being used, how the hardware is connected, bandwidth of the network, backup software, and the speed of server's I/O system. Here we will discuss some of the hardware choices that are available and their pros and cons. These choices are as follows −

- Tape Technology
- Disk Backups

Tape Technology

The tape choice can be categorized as follows −

- Tape media
- Standalone tape drives
- Tape stackers
- Tape silos

Tape Media

There exists several varieties of tape media. Some tape media standards are listed in the table below −

Tape Media	Capacity	I/O rates
DLT	40 GB	3 MB/s
3490e	1.6 GB	3 MB/s

8 mm	14 GB	1 MB/s

Other factors that need to be considered are as follows −

- Reliability of the tape medium
- Cost of tape medium per unit
- Scalability
- Cost of upgrades to tape system
- Cost of tape medium per unit
- Shelf life of tape medium

Standalone Tape Drives

The tape drives can be connected in the following ways −

- Direct to the server
- As network available devices
- Remotely to other machine

There could be issues in connecting the tape drives to a data warehouse.

- Consider the server is a 48node MPP machine. We do not know the node to connect the tape drive and we do not know how to spread them over the server nodes to get the optimal performance with least disruption of the server and least internal I/O latency.
- Connecting the tape drive as a network available device requires the network to be up to the job of the huge data transfer rates. Make sure that sufficient bandwidth is available during the time you require it.
- Connecting the tape drives remotely also require high bandwidth.

Tape Stackers

The method of loading multiple tapes into a single tape drive is known as tape stackers. The stacker dismounts the current tape when it has finished with it and loads the next tape, hence only one tape is available at a time to be accessed. The price and the capabilities may vary, but the common ability is that they can perform unattended backups.

Tape Silos

Tape silos provide large store capacities. Tape silos can store and manage thousands of tapes. They can integrate multiple tape drives. They have the software and hardware to label and store the tapes they store. It is very common for the silo to be connected remotely over a network or a dedicated link. We should ensure that the bandwidth of the connection is up to the job.

Disk Backups

Methods of disk backups are −

- Disk-to-disk backups
- Mirror breaking

These methods are used in the OLTP system. These methods minimize the database downtime and maximize the availability.

Disk-to-Disk Backups

Here backup is taken on the disk rather on the tape. Disk-to-disk backups are done for the following reasons −

- Speed of initial backups
- Speed of restore

Backing up the data from disk to disk is much faster than to the tape. However it is the intermediate step of backup. Later the data is backed up on the tape. The other advantage of disk-to-disk backups is that it gives you an online copy of the latest backup.

Mirror Breaking

The idea is to have disks mirrored for resilience during the working day. When backup is required, one of the mirror sets can be broken out. This technique is a variant of disk-to-disk backups.

Note − The database may need to be shutdown to guarantee consistency of the backup.

Optical Jukeboxes

Optical jukeboxes allow the data to be stored near line. This technique allows a large number of optical disks to be managed in the same way as a tape stacker or a tape silo. The drawback of this technique is that it has slow write speed than disks. But the optical media provides long-life and reliability that makes them a good choice of medium for archiving.

Software Backups

There are software tools available that help in the backup process. These software tools come as a package. These tools not only take backup, they can effectively manage and control the backup strategies. There are many software packages available in the market. Some of them are listed in the following table −

Package Name	**Vendor**
Networker	Legato
ADSM	IBM
Epoch	Epoch Systems
Omniback II	HP
Alexandria	Sequent

Criteria for Choosing Software Packages

The criteria for choosing the best software package are listed below −

- How scalable is the product as tape drives are added?
- Does the package have client-server option, or must it run on the database server itself?
- Will it work in cluster and MPP environments?
- What degree of parallelism is required?
- What platforms are supported by the package?
- Does the package support easy access to information about tape contents?

- Is the package database aware?
- What tape drive and tape media are supported by the package?

Data Warehousing - Tuning

A data warehouse keeps evolving and it is unpredictable what query the user is going to post in the future. Therefore it becomes more difficult to tune a data warehouse system. In this chapter, we will discuss how to tune the different aspects of a data warehouse such as performance, data load, queries, etc.

Difficulties in Data Warehouse Tuning

Tuning a data warehouse is a difficult procedure due to following reasons −

- Data warehouse is dynamic; it never remains constant.
- It is very difficult to predict what query the user is going to post in the future.
- Business requirements change with time.
- Users and their profiles keep changing.
- The user can switch from one group to another.
- The data load on the warehouse also changes with time.

Note − It is very important to have a complete knowledge of data warehouse.

Performance Assessment

Here is a list of objective measures of performance −

- Average query response time
- Scan rates
- Time used per day query
- Memory usage per process
- I/O throughput rates

Following are the points to remember.

- It is necessary to specify the measures in service level agreement (SLA).
- It is of no use trying to tune response time, if they are already better than those required.

- It is essential to have realistic expectations while making performance assessment.
- It is also essential that the users have feasible expectations.
- To hide the complexity of the system from the user, aggregations and views should be used.
- It is also possible that the user can write a query you had not tuned for.

Data Load Tuning

Data load is a critical part of overnight processing. Nothing else can run until data load is complete. This is the entry point into the system.

Note − If there is a delay in transferring the data, or in arrival of data then the entire system is affected badly. Therefore it is very important to tune the data load first.

There are various approaches of tuning data load that are discussed below −

- The very common approach is to insert data using the **SQL Layer**. In this approach, normal checks and constraints need to be performed. When the data is inserted into the table, the code will run to check for enough space to insert the data. If sufficient space is not available, then more space may have to be allocated to these tables. These checks take time to perform and are costly to CPU.
- The second approach is to bypass all these checks and constraints and place the data directly into the preformatted blocks. These blocks are later written to the database. It is faster than the first approach, but it can work only with whole blocks of data. This can lead to some space wastage.
- The third approach is that while loading the data into the table that already contains the table, we can maintain indexes.
- The fourth approach says that to load the data in tables that already contain data, **drop the indexes & recreate them** when the data load is complete. The choice between the third and the fourth approach depends on how much data is already loaded and how many indexes need to be rebuilt.

Integrity Checks

Integrity checking highly affects the performance of the load. Following are the points to remember −

- Integrity checks need to be limited because they require heavy processing power.
- Integrity checks should be applied on the source system to avoid performance degrade of data load.

Tuning Queries

We have two kinds of queries in data warehouse −

- Fixed queries
- Ad hoc queries

Fixed Queries

Fixed queries are well defined. Following are the examples of fixed queries −

- regular reports
- Canned queries
- Common aggregations

Tuning the fixed queries in a data warehouse is same as in a relational database system. The only difference is that the amount of data to be queried may be different. It is good to store the most successful execution plan while testing fixed queries. Storing these executing plan will allow us to spot changing data size and data skew, as it will cause the execution plan to change.

Note − We cannot do more on fact table but while dealing with dimension tables or the aggregations, the usual collection of SQL tweaking, storage mechanism, and access methods can be used to tune these queries.

Ad hoc Queries

To understand ad hoc queries, it is important to know the ad hoc users of the data warehouse. For each user or group of users, you need to know the following −

- The number of users in the group
- Whether they use ad hoc queries at regular intervals of time

- Whether they use ad hoc queries frequently
- Whether they use ad hoc queries occasionally at unknown intervals.
- The maximum size of query they tend to run
- The average size of query they tend to run
- Whether they require drill-down access to the base data
- The elapsed login time per day
- The peak time of daily usage
- The number of queries they run per peak hour

Points to Note

- It is important to track the user's profiles and identify the queries that are run on a regular basis.
- It is also important that the tuning performed does not affect the performance.
- Identify similar and ad hoc queries that are frequently run.
- If these queries are identified, then the database will change and new indexes can be added for those queries.
- If these queries are identified, then new aggregations can be created specifically for those queries that would result in their efficient execution.

Data Warehousing - Testing

Testing is very important for data warehouse systems to make them work correctly and efficiently. There are three basic levels of testing performed on a data warehouse −

- Unit testing
- Integration testing
- System testing

Unit Testing

- In unit testing, each component is separately tested.
- Each module, i.e., procedure, program, SQL Script, Unix shell is tested.
- This test is performed by the developer.

Integration Testing

- In integration testing, the various modules of the application are brought together and then tested against the number of inputs.
- It is performed to test whether the various components do well after integration.

System Testing

- In system testing, the whole data warehouse application is tested together.
- The purpose of system testing is to check whether the entire system works correctly together or not.
- System testing is performed by the testing team.
- Since the size of the whole data warehouse is very large, it is usually possible to perform minimal system testing before the test plan can be enacted.

Test Schedule

First of all, the test schedule is created in the process of developing the test plan. In this schedule, we predict the estimated time required for the testing of the entire data warehouse system.

There are different methodologies available to create a test schedule, but none of them are perfect because the data warehouse is very complex and large. Also the data warehouse system is evolving in nature. One may face the following issues while creating a test schedule −

- A simple problem may have a large size of query that can take a day or more to complete, i.e., the query does not complete in a desired time scale.
- There may be hardware failures such as losing a disk or human errors such as accidentally deleting a table or overwriting a large table.

Note − Due to the above-mentioned difficulties, it is recommended to always double the amount of time you would normally allow for testing.

Testing Backup Recovery

Testing the backup recovery strategy is extremely important. Here is the list of scenarios for which this testing is needed −

- Media failure
- Loss or damage of table space or data file
- Loss or damage of redo log file
- Loss or damage of control file
- Instance failure
- Loss or damage of archive file
- Loss or damage of table
- Failure during data failure

Testing Operational Environment

There are a number of aspects that need to be tested. These aspects are listed below.

- **Security** − A separate security document is required for security testing. This document contains a list of disallowed operations and devising tests for each.
- **Scheduler** − Scheduling software is required to control the daily operations of a data warehouse. It needs to be tested during system testing. The scheduling software requires an interface with the data warehouse, which will need the scheduler to control overnight processing and the management of aggregations.

- **Disk Configuration.** − Disk configuration also needs to be tested to identify I/O bottlenecks. The test should be performed with multiple times with different settings.
- **Management Tools.** − It is required to test all the management tools during system testing. Here is the list of tools that need to be tested.
  - Event manager
  - System manager
  - Database manager
  - Configuration manager
  - Backup recovery manager

Testing the Database

The database is tested in the following three ways −

- **Testing the database manager and monitoring tools** − To test the database manager and the monitoring tools, they should be used in the creation, running, and management of test database.
- **Testing database features** − Here is the list of features that we have to test −
  - Querying in parallel
  - Create index in parallel
  - Data load in parallel
- **Testing database performance** − Query execution plays a very important role in data warehouse performance measures. There are sets of fixed queries that need to be run regularly and they should be tested. To test ad hoc queries, one should go through the user requirement document and understand the business completely. Take time to test the most awkward queries that the business is likely to ask against different index and aggregation strategies.

Testing the Application

- All the managers should be integrated correctly and work in order to ensure that the end-to-end load, index, aggregate and queries work as per the expectations.
- Each function of each manager should work correctly

- It is also necessary to test the application over a period of time.
- Week end and month-end tasks should also be tested.

Logistic of the Test

The aim of system test is to test all of the following areas −

- Scheduling software
- Day-to-day operational procedures
- Backup recovery strategy
- Management and scheduling tools
- Overnight processing
- Query performance

Note − The most important point is to test the scalability. Failure to do so will leave us a system design that does not work when the system grows.

Data Warehousing - Future Aspects

Following are the future aspects of data warehousing.

- As we have seen that the size of the open database has grown approximately double its magnitude in the last few years, it shows the significant value that it contains.
- As the size of the databases grow, the estimates of what constitutes a very large database continues to grow.
- The hardware and software that are available today do not allow to keep a large amount of data online. For example, a Telco call record requires 10TB of data to be kept online, which is just a size of one month's record. If it requires to keep records of sales, marketing customer, employees, etc., then the size will be more than 100 TB.
- The record contains textual information and some multimedia data. Multimedia data cannot be easily manipulated as text data. Searching the multimedia data is not an easy task, whereas textual information can be retrieved by the relational software available today.

- Apart from size planning, it is complex to build and run data warehouse systems that are ever increasing in size. As the number of users increases, the size of the data warehouse also increases. These users will also require to access the system.
- With the growth of the Internet, there is a requirement of users to access data online.

Hence the future shape of data warehouse will be very different from what is being created today.

Data Mining - Overview

There is a huge amount of data available in the Information Industry. This data is of no use until it is converted into useful information. It is necessary to analyze this huge amount of data and extract useful information from it.

Extraction of information is not the only process we need to perform; data mining also involves other processes such as Data Cleaning, Data Integration, Data Transformation, Data Mining, Pattern Evaluation and Data Presentation. Once all these processes are over, we would be able to use this information in many applications such as Fraud Detection, Market Analysis, Production Control, Science Exploration, etc.

What is Data Mining?

Data Mining is defined as extracting information from huge sets of data. In other words, we can say that data mining is the procedure of mining knowledge from data. The information or knowledge extracted so can be used for any of the following applications −

- Market Analysis
- Fraud Detection
- Customer Retention
- Production Control
- Science Exploration

Data Mining Applications

Data mining is highly useful in the following domains −

- Market Analysis and Management

- Corporate Analysis & Risk Management
- Fraud Detection

Apart from these, data mining can also be used in the areas of production control, customer retention, science exploration, sports, astrology, and Internet Web Surf-Aid

Market Analysis and Management

Listed below are the various fields of market where data mining is used −

- **Customer Profiling** − Data mining helps determine what kind of people buy what kind of products.
- **Identifying Customer Requirements** − Data mining helps in identifying the best products for different customers. It uses prediction to find the factors that may attract new customers.
- **Cross Market Analysis** − Data mining performs Association/correlations between product sales.
- **Target Marketing** − Data mining helps to find clusters of model customers who share the same characteristics such as interests, spending habits, income, etc.
- **Determining Customer purchasing pattern** − Data mining helps in determining customer purchasing pattern.
- **Providing Summary Information** − Data mining provides us various multidimensional summary reports.

Corporate Analysis and Risk Management

Data mining is used in the following fields of the Corporate Sector −

- **Finance Planning and Asset Evaluation** − It involves cash flow analysis and prediction, contingent claim analysis to evaluate assets.
- **Resource Planning** − It involves summarizing and comparing the resources and spending.
- **Competition** − It involves monitoring competitors and market directions.

Fraud Detection

Data mining is also used in the fields of credit card services and telecommunication to detect frauds. In fraud telephone calls, it helps to find the destination of the call, duration of the call, time of the day or week, etc. It also analyzes the patterns that deviate from expected norms.

Data Mining - Tasks

Data mining deals with the kind of patterns that can be mined. On the basis of the kind of data to be mined, there are two categories of functions involved in Data Mining −

- Descriptive
- Classification and Prediction

Descriptive Function

The descriptive function deals with the general properties of data in the database. Here is the list of descriptive functions −

- Class/Concept Description
- Mining of Frequent Patterns
- Mining of Associations
- Mining of Correlations
- Mining of Clusters

Class/Concept Description

Class/Concept refers to the data to be associated with the classes or concepts. For example, in a company, the classes of items for sales include computer and printers, and concepts of customers include big spenders and budget spenders. Such descriptions of a class or a concept are called class/concept descriptions. These descriptions can be derived by the following two ways −

- **Data Characterization** − This refers to summarizing data of class under study. This class under study is called as Target Class.
- **Data Discrimination** − It refers to the mapping or classification of a class with some predefined group or class.

Mining of Frequent Patterns

Frequent patterns are those patterns that occur frequently in transactional data. Here is the list of kind of frequent patterns −

- **Frequent Item Set** − It refers to a set of items that frequently appear together, for example, milk and bread.
- **Frequent Subsequence** − A sequence of patterns that occur frequently such as purchasing a camera is followed by memory card.
- **Frequent Sub Structure** − Substructure refers to different structural forms, such as graphs, trees, or lattices, which may be combined with item-sets or subsequences.

Mining of Association

Associations are used in retail sales to identify patterns that are frequently purchased together. This process refers to the process of uncovering the relationship among data and determining association rules.

For example, a retailer generates an association rule that shows that 70% of time milk is sold with bread and only 30% of times biscuits are sold with bread.

Mining of Correlations

It is a kind of additional analysis performed to uncover interesting statistical correlations between associated-attribute-value pairs or between two item sets to analyze that if they have positive, negative or no effect on each other.

Mining of Clusters

Cluster refers to a group of similar kind of objects. Cluster analysis refers to forming group of objects that are very similar to each other but are highly different from the objects in other clusters.

Classification and Prediction

Classification is the process of finding a model that describes the data classes or concepts. The purpose is to be able to use this model to predict the class of objects whose class label is unknown. This derived model is based on the analysis of sets of training data. The derived model can be presented in the following forms −

- Classification (IF-THEN) Rules
- Decision Trees
- Mathematical Formulae
- Neural Networks

The list of functions involved in these processes are as follows −

- **Classification** − It predicts the class of objects whose class label is unknown. Its objective is to find a derived model that describes and distinguishes data classes or concepts. The Derived Model is based on the analysis set of training data i.e. the data object whose class label is well known.
- **Prediction** − It is used to predict missing or unavailable numerical data values rather than class labels. Regression Analysis is generally used for prediction. Prediction can also be used for identification of distribution trends based on available data.
- **Outlier Analysis** − Outliers may be defined as the data objects that do not comply with the general behavior or model of the data available.
- **Evolution Analysis** − Evolution analysis refers to the description and model regularities or trends for objects whose behavior changes over time.

Data Mining Task Primitives

- We can specify a data mining task in the form of a data mining query.
- This query is input to the system.
- A data mining query is defined in terms of data mining task primitives.

Note − These primitives allow us to communicate in an interactive manner with the data mining system. Here is the list of Data Mining Task Primitives −

- Set of task relevant data to be mined.
- Kind of knowledge to be mined.
- Background knowledge to be used in discovery process.
- Interestingness measures and thresholds for pattern evaluation.
- Representation for visualizing the discovered patterns.

Set of task relevant data to be mined

This is the portion of database in which the user is interested. This portion includes the following −

- Database Attributes
- Data Warehouse dimensions of interest

Kind of knowledge to be mined

It refers to the kind of functions to be performed. These functions are −

- Characterization
- Discrimination
- Association and Correlation Analysis
- Classification
- Prediction
- Clustering
- Outlier Analysis
- Evolution Analysis

Background knowledge

The background knowledge allows data to be mined at multiple levels of abstraction. For example, the Concept hierarchies are one of the background knowledge that allows data to be mined at multiple levels of abstraction.

Interestingness measures and thresholds for pattern evaluation

This is used to evaluate the patterns that are discovered by the process of knowledge discovery. There are different interesting measures for different kind of knowledge.

Representation for visualizing the discovered patterns

This refers to the form in which discovered patterns are to be displayed. These representations may include the following. −

- Rules
- Tables

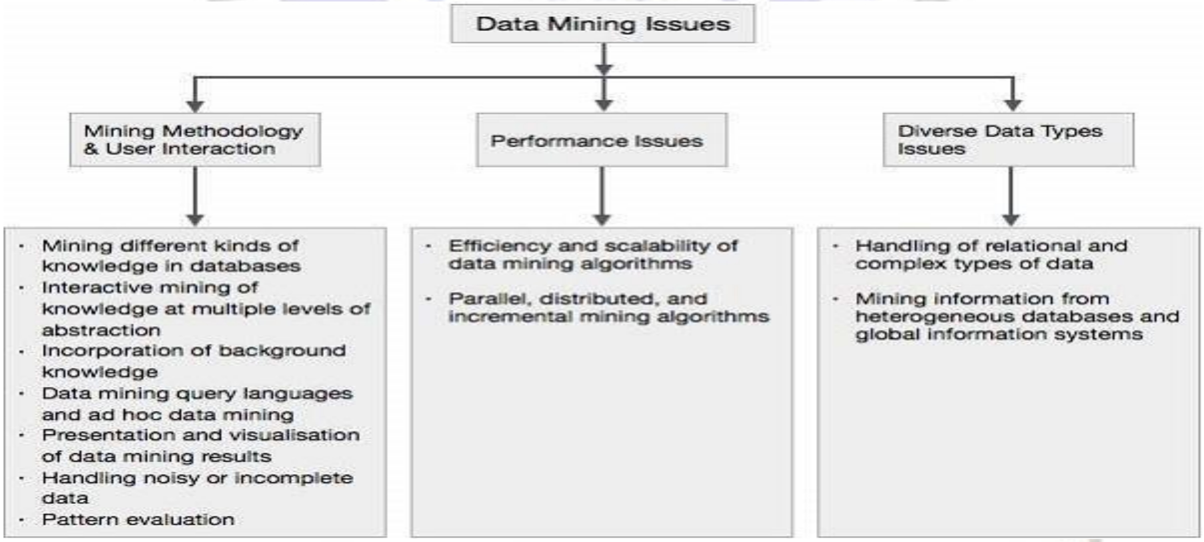
- Charts
- Graphs
- Decision Trees
- Cubes

Data Mining - Issues

Data mining is not an easy task, as the algorithms used can get very complex and data is not always available at one place. It needs to be integrated from various heterogeneous data sources. These factors also create some issues. Here in this tutorial, we will discuss the major issues regarding −

- Mining Methodology and User Interaction
- Performance Issues
- Diverse Data Types Issues

The following diagram describes the major issues.


Data Mining Issues
Mining Methodology & User Interaction
Performance Issues
Diverse Data Types Issues
· Mining different kinds of knowledge in databases
· Interactive mining of knowledge at multiple levels of abstraction
· Incorporation of background knowledge
· Data mining query languages and ad hoc data mining
· Presentation and visualisation of data mining results
· Handling noisy or incomplete data
· Pattern evaluation
· Efficiency and scalability of data mining algorithms
· Parallel, distributed, and incremental mining algorithms
· Handling of relational and complex types of data
· Mining information from heterogeneous databases and global information systems

Mining Methodology and User Interaction Issues

It refers to the following kinds of issues −

- **Mining different kinds of knowledge in databases** − Different users may be interested in different kinds of knowledge. Therefore it is necessary for data mining to cover a broad range of knowledge discovery task.

- **Interactive mining of knowledge at multiple levels of abstraction** − The data mining process needs to be interactive because it allows users to focus the search for patterns, providing and refining data mining requests based on the returned results.
- **Incorporation of background knowledge** − To guide discovery process and to express the discovered patterns, the background knowledge can be used. Background knowledge may be used to express the discovered patterns not only in concise terms but at multiple levels of abstraction.
- **Data mining query languages and ad hoc data mining** − Data Mining Query language that allows the user to describe ad hoc mining tasks, should be integrated with a data warehouse query language and optimized for efficient and flexible data mining.
- **Presentation and visualization of data mining results** − Once the patterns are discovered it needs to be expressed in high level languages, and visual representations. These representations should be easily understandable.
- **Handling noisy or incomplete data** − The data cleaning methods are required to handle the noise and incomplete objects while mining the data regularities. If the data cleaning methods are not there then the accuracy of the discovered patterns will be poor.
- **Pattern evaluation** − The patterns discovered should be interesting because either they represent common knowledge or lack novelty.

Performance Issues

There can be performance-related issues such as follows −

- **Efficiency and scalability of data mining algorithms** − In order to effectively extract the information from huge amount of data in databases, data mining algorithm must be efficient and scalable.
- **Parallel, distributed, and incremental mining algorithms** − The factors such as huge size of databases, wide distribution of data, and complexity of data mining methods motivate the development of parallel and distributed data mining algorithms. These algorithms divide the data into partitions which is further processed in a parallel fashion. Then the results from the partitions is merged. The incremental algorithms, update databases without mining the data again from scratch.

Diverse Data Types Issues

- **Handling of relational and complex types of data** − The database may contain complex data objects, multimedia data objects, spatial data, temporal data etc. It is not possible for one system to mine all these kind of data.
- **Mining information from heterogeneous databases and global information systems** − The data is available at different data sources on LAN or WAN. These data source may be structured, semi structured or unstructured. Therefore mining the knowledge from them adds challenges to data mining.

Data Mining - Evaluation

Data Warehouse

A data warehouse exhibits the following characteristics to support the management's decision-making process −

- **Subject Oriented** − Data warehouse is subject oriented because it provides us the information around a subject rather than the organization's ongoing operations. These subjects can be product, customers, suppliers, sales, revenue, etc. The data warehouse does not focus on the ongoing operations, rather it focuses on modelling and analysis of data for decision-making.
- **Integrated** − Data warehouse is constructed by integration of data from heterogeneous sources such as relational databases, flat files etc. This integration enhances the effective analysis of data.
- **Time Variant** − The data collected in a data warehouse is identified with a particular time period. The data in a data warehouse provides information from a historical point of view.
- **Non-volatile** − Nonvolatile means the previous data is not removed when new data is added to it. The data warehouse is kept separate from the operational database therefore frequent changes in operational database is not reflected in the data warehouse.

Data Warehousing

Data warehousing is the process of constructing and using the data warehouse. A data warehouse is constructed by integrating the data from multiple heterogeneous sources. It supports analytical reporting, structured and/or ad hoc queries, and decision making.

Data warehousing involves data cleaning, data integration, and data consolidations. To integrate heterogeneous databases, we have the following two approaches −

- Query Driven Approach
- Update Driven Approach

Query-Driven Approach

This is the traditional approach to integrate heterogeneous databases. This approach is used to build wrappers and integrators on top of multiple heterogeneous databases. These integrators are also known as mediators.

Process of Query Driven Approach

- When a query is issued to a client side, a metadata dictionary translates the query into the queries, appropriate for the individual heterogeneous site involved.
- Now these queries are mapped and sent to the local query processor.
- The results from heterogeneous sites are integrated into a global answer set.

Disadvantages

This approach has the following disadvantages −

- The Query Driven Approach needs complex integration and filtering processes.
- It is very inefficient and very expensive for frequent queries.
- This approach is expensive for queries that require aggregations.

Update-Driven Approach

Today's data warehouse systems follow update-driven approach rather than the traditional approach discussed earlier. In the update-driven approach, the information from multiple heterogeneous sources is integrated in advance and stored in a warehouse. This information is available for direct querying and analysis.

Advantages

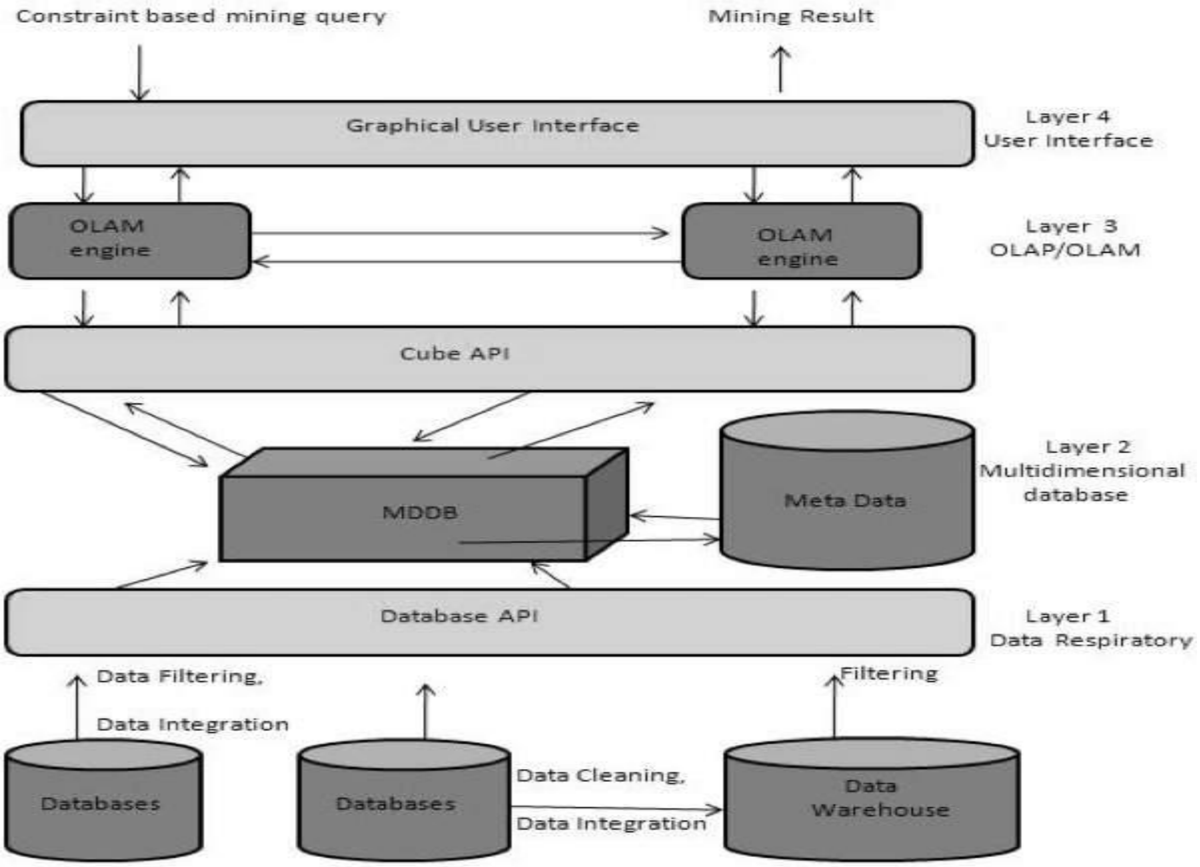
This approach has the following advantages −

- This approach provides high performance.
- The data can be copied, processed, integrated, annotated, summarized and restructured in the semantic data store in advance.

Query processing does not require interface with the processing at local sources.

From Data Warehousing (OLAP) to Data Mining (OLAM)

Online Analytical Mining integrates with Online Analytical Processing with data mining and mining knowledge in multidimensional databases. Here is the diagram that shows the integration of both OLAP and OLAM −



Importance of OLAM

OLAM is important for the following reasons −

- **High quality of data in data warehouses** − The data mining tools are required to work on integrated, consistent, and cleaned data. These steps are very costly in the preprocessing of data. The data warehouses constructed by such preprocessing are valuable sources of high quality data for OLAP and data mining as well.
- **Available information processing infrastructure surrounding data warehouses** − Information processing infrastructure refers to accessing, integration, consolidation, and transformation of multiple heterogeneous databases, web-accessing and service facilities, reporting and OLAP analysis tools.
- **OLAP−based exploratory data analysis** − Exploratory data analysis is required for effective data mining. OLAM provides facility for data mining on various subset of data and at different levels of abstraction.
- **Online selection of data mining functions** − Integrating OLAP with multiple data mining functions and online analytical mining provide users with the flexibility to select desired data mining functions and swap data mining tasks dynamically.

Data Mining - Terminologies

Data Mining

Data mining is defined as extracting the information from a huge set of data. In other words we can say that data mining is mining the knowledge from data. This information can be used for any of the following applications −

- Market Analysis
- Fraud Detection
- Customer Retention
- Production Control
- Science Exploration

Data Mining Engine

Data mining engine is very essential to the data mining system. It consists of a set of functional modules that perform the following functions −

- Characterization
- Association and Correlation Analysis
- Classification
- Prediction
- Cluster analysis
- Outlier analysis
- Evolution analysis

Knowledge Base

This is the domain knowledge. This knowledge is used to guide the search or evaluate the interestingness of the resulting patterns.

Knowledge Discovery

Some people treat data mining same as knowledge discovery, while others view data mining as an essential step in the process of knowledge discovery. Here is the list of steps involved in the knowledge discovery process −

- Data Cleaning
- Data Integration
- Data Selection
- Data Transformation
- Data Mining
- Pattern Evaluation
- Knowledge Presentation

User interface

User interface is the module of data mining system that helps the communication between users and the data mining system. User Interface allows the following functionalities −

- Interact with the system by specifying a data mining query task.
- Providing information to help focus the search.
- Mining based on the intermediate data mining results.
- Browse database and data warehouse schemas or data structures.
- Evaluate mined patterns.
- Visualize the patterns in different forms.

Data Integration

Data Integration is a data preprocessing technique that merges the data from multiple heterogeneous data sources into a coherent data store. Data integration may involve inconsistent data and therefore needs data cleaning.

Data Cleaning

Data cleaning is a technique that is applied to remove the noisy data and correct the inconsistencies in data. Data cleaning involves transformations to correct the wrong data. Data cleaning is performed as a data preprocessing step while preparing the data for a data warehouse.

Data Selection

Data Selection is the process where data relevant to the analysis task are retrieved from the database. Sometimes data transformation and consolidation are performed before the data selection process.

Clusters

Cluster refers to a group of similar kind of objects. Cluster analysis refers to forming group of objects that are very similar to each other but are highly different from the objects in other clusters.

Data Transformation

In this step, data is transformed or consolidated into forms appropriate for mining, by performing summary or aggregation operations.

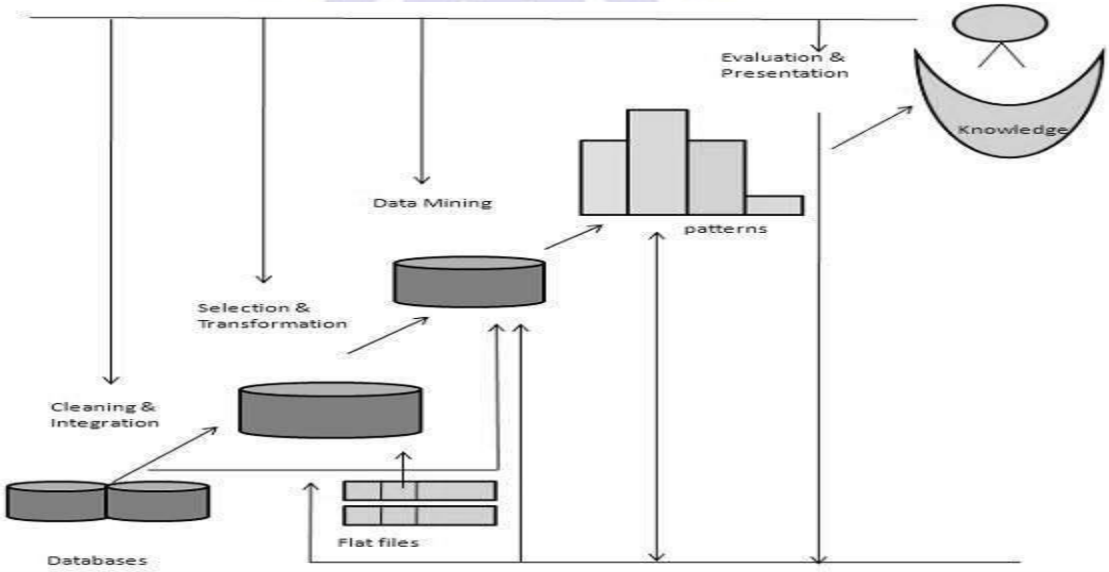
Data Mining - Knowledge Discovery

What is Knowledge Discovery?

Some people don't differentiate data mining from knowledge discovery while others view data mining as an essential step in the process of knowledge discovery. Here is the list of steps involved in the knowledge discovery process −

- **Data Cleaning** − In this step, the noise and inconsistent data is removed.
- **Data Integration** − In this step, multiple data sources are combined.
- **Data Selection** − In this step, data relevant to the analysis task are retrieved from the database.
- **Data Transformation** − In this step, data is transformed or consolidated into forms appropriate for mining by performing summary or aggregation operations.
- **Data Mining** − In this step, intelligent methods are applied in order to extract data patterns.
- **Pattern Evaluation** − In this step, data patterns are evaluated.
- **Knowledge Presentation** − In this step, knowledge is represented.

The following diagram shows the process of knowledge discovery −



Data Mining - Systems

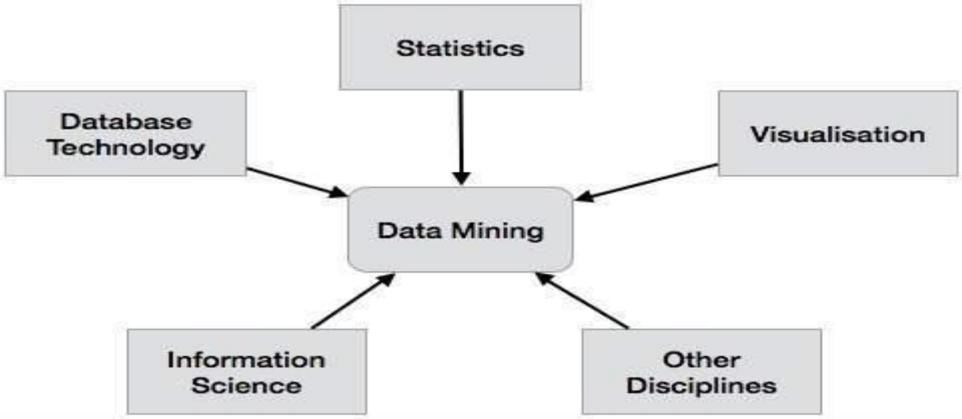
There is a large variety of data mining systems available. Data mining systems may integrate techniques from the following −

- Spatial Data Analysis
- Information Retrieval
- Pattern Recognition
- Image Analysis
- Signal Processing
- Computer Graphics
- Web Technology
- Business
- Bioinformatics

Data Mining System Classification

A data mining system can be classified according to the following criteria −

- Database Technology
- Statistics
- Machine Learning
- Information Science
- Visualization
- Other Disciplines



Apart from these, a data mining system can also be classified based on the kind of (a) databases mined, (b) knowledge mined, (c) techniques utilized, and (d) applications adapted.

Classification Based on the Databases Mined

We can classify a data mining system according to the kind of databases mined. Database system can be classified according to different criteria such as data models, types of data, etc. And the data mining system can be classified accordingly.

For example, if we classify a database according to the data model, then we may have a relational, transactional, object-relational, or data warehouse mining system.

Classification Based on the kind of Knowledge Mined

We can classify a data mining system according to the kind of knowledge mined. It means the data mining system is classified on the basis of functionalities such as −

- Characterization
- Discrimination
- Association and Correlation Analysis
- Classification
- Prediction
- Outlier Analysis
- Evolution Analysis

Classification Based on the Techniques Utilized

We can classify a data mining system according to the kind of techniques used. We can describe these techniques according to the degree of user interaction involved or the methods of analysis employed.

Classification Based on the Applications Adapted

We can classify a data mining system according to the applications adapted. These applications are as follows −

- Finance
- Telecommunications
- DNA
- Stock Markets
- E-mail

Integrating a Data Mining System with a DB/DW System

If a data mining system is not integrated with a database or a data warehouse system, then there will be no system to communicate with. This scheme is known as the non-coupling scheme. In this scheme, the main focus is on data mining design and on developing efficient and effective algorithms for mining the available data sets.

The list of Integration Schemes is as follows −

- **No Coupling** − In this scheme, the data mining system does not utilize any of the database or data warehouse functions. It fetches the data from a particular source and processes that data using some data mining algorithms. The data mining result is stored in another file.
- **Loose Coupling** − In this scheme, the data mining system may use some of the functions of database and data warehouse system. It fetches the data from the data respiratory managed by these systems and performs data mining on that data. It then stores the mining result either in a file or in a designated place in a database or in a data warehouse.

- **Semi−tight Coupling** − In this scheme, the data mining system is linked with a database or a data warehouse system and in addition to that, efficient implementations of a few data mining primitives can be provided in the database.

- **Tight coupling** − In this coupling scheme, the data mining system is smoothly integrated into the database or data warehouse system. The data mining subsystem is treated as one functional component of an information system.

Data Mining - Query Language

The Data Mining Query Language (DMQL) was proposed by Han, Fu, Wang, et al. for the DBMiner data mining system. The Data Mining Query Language is actually based on the Structured Query Language (SQL). Data Mining Query Languages can be designed to support ad hoc and interactive data mining. This DMQL provides commands for specifying primitives. The DMQL can work with databases and data warehouses as well. DMQL can be used to define data mining tasks. Particularly we examine how to define data warehouses and data marts in DMQL.

Syntax for Task-Relevant Data Specification

Here is the syntax of DMQL for specifying task-relevant data −

```
use database database_name

or

use data warehouse data_warehouse_name
in relevance to att_or_dim_list
from relation(s)/cube(s) [where condition]
order by order_list
group by grouping_list
```

Syntax for Specifying the Kind of Knowledge

Here we will discuss the syntax for Characterization, Discrimination, Association, Classification, and Prediction.

Characterization

The syntax for characterization is −

```
mine characteristics [as pattern_name]
```

```
  analyze  {measure(s) }
```

The analyze clause, specifies aggregate measures, such as count, sum, or count%.

For example −

```
Description describing customer purchasing habits.
mine characteristics as customerPurchasing
analyze count%
```

Discrimination

The syntax for Discrimination is −

```
mine comparison [as {pattern_name]}
For {target_class } where  {t arget_condition }
{versus  {contrast_class_i }
where {contrast_condition_i}}
analyze  {measure(s) }
```

For example, a user may define big spenders as customers who purchase items that cost $100 or more on an average; and budget spenders as customers who purchase items at less than $100 on an average. The mining of discriminant descriptions for customers from each of these categories can be specified in the DMQL as −

```
mine comparison as purchaseGroups
for bigSpenders where avg(I.price) ≥$100
versus budgetSpenders where avg(I.price)< $100
analyze count
```

Association

The syntax for Association is−

```
mine associations [ as {pattern_name} ]
{matching {metapattern} }
```

For Example −

```
mine associations as buyingHabits
matching P(X:customer,W) ^ Q(X,Y) ≥ buys(X,Z)
```

where X is key of customer relation; P and Q are predicate variables; and W, Y, and Z are object variables.

Classification

The syntax for Classification is −

```
mine classification [as pattern_name]
analyze classifying_attribute_or_dimension
```

For example, to mine patterns, classifying customer credit rating where the classes are determined by the attribute credit_rating, and mine classification is determined as classifyCustomerCreditRating.

```
analyze credit_rating
```

Prediction

The syntax for prediction is −

```
mine prediction [as pattern_name]
analyze prediction_attribute_or_dimension
{set {attribute_or_dimension_i= value_i}}
```

Syntax for Concept Hierarchy Specification

To specify concept hierarchies, use the following syntax −

```
use hierarchy <hierarchy> for <attribute_or_dimension>
```

We use different syntaxes to define different types of hierarchies such as−

```
-schema hierarchies
define hierarchy time_hierarchy on date as [date,month quarter,year]
-
set-grouping hierarchies
define hierarchy age_hierarchy for age on customer as
level1: {young, middle_aged, senior} < level0: all
level2: {20, ..., 39} < level1: young
level3: {40, ..., 59} < level1: middle_aged
level4: {60, ..., 89} < level1: senior

-operation-derived hierarchies
define hierarchy age_hierarchy  for age  on customer  as
{age_category(1), ..., age_category(5)}
:= cluster(default, age, 5) < all(age)

-rule-based hierarchies
```

```
define hierarchy profit_margin_hierarchy  on item  as
level_1: low_profit_margin < level_0:  all

if (price - cost)< $50
  level_1:  medium-profit_margin < level_0:  all

if ((price - cost) > $50)  and ((price - cost) ≤ $250))
  level_1:  high_profit_margin < level_0:  all
```

Syntax for Interestingness Measures Specification

Interestingness measures and thresholds can be specified by the user with the statement −

```
with <interest_measure_name>  threshold = threshold_value
```

For Example −

```
with support threshold = 0.05
with confidence threshold = 0.7
```

Syntax for Pattern Presentation and Visualization Specification

We have a syntax, which allows users to specify the display of discovered patterns in one or more forms.

```
display as <result_form>
```

For Example −

```
display as table
```

Full Specification of DMQL

As a market manager of a company, you would like to characterize the buying habits of customers who can purchase items priced at no less than $100; with respect to the customer's age, type of item purchased, and the place where the item was purchased. You would like to know the percentage of customers having that characteristic. In particular, you are only interested in purchases made in Canada, and paid with an American Express credit card. You would like to view the resulting descriptions in the form of a table.

```
use database AllElectronics_db
use hierarchy location_hierarchy for B.address
mine characteristics as customerPurchasing
analyze count%
```

```
in relevance to C.age,I.type,I.place_made
from customer C, item I, purchase P, items_sold S,  branch B
where I.item_ID = S.item_ID and P.cust_ID = C.cust_ID and
P.method_paid = "AmEx" and B.address = "Canada" and I.price ≥ 100
with noise threshold = 5%
display as table
```

Data Mining Languages Standardization

Standardizing the Data Mining Languages will serve the following purposes −

- Helps systematic development of data mining solutions.
- Improves interoperability among multiple data mining systems and functions.
- Promotes education and rapid learning.
- Promotes the use of data mining systems in industry and society.

Data Mining - Classification & Prediction

There are two forms of data analysis that can be used for extracting models describing important classes or to predict future data trends. These two forms are as follows −

- Classification
- Prediction

Classification models predict categorical class labels; and prediction models predict continuous valued functions. For example, we can build a classification model to categorize bank loan applications as either safe or risky, or a prediction model to predict the expenditures in dollars of potential customers on computer equipment given their income and occupation.

What is classification?

Following are the examples of cases where the data analysis task is Classification −

- A bank loan officer wants to analyze the data in order to know which customer (loan applicant) are risky or which are safe.
- A marketing manager at a company needs to analyze a customer with a given profile, who will buy a new computer.

In both of the above examples, a model or classifier is constructed to predict the categorical labels. These labels are risky or safe for loan application data and yes or no for marketing data.

What is prediction?

Following are the examples of cases where the data analysis task is Prediction −

Suppose the marketing manager needs to predict how much a given customer will spend during a sale at his company. In this example we are bothered to predict a numeric value. Therefore the data analysis task is an example of numeric prediction. In this case, a model or a predictor will be constructed that predicts a continuous-valued-function or ordered value.

Note − Regression analysis is a statistical methodology that is most often used for numeric prediction.

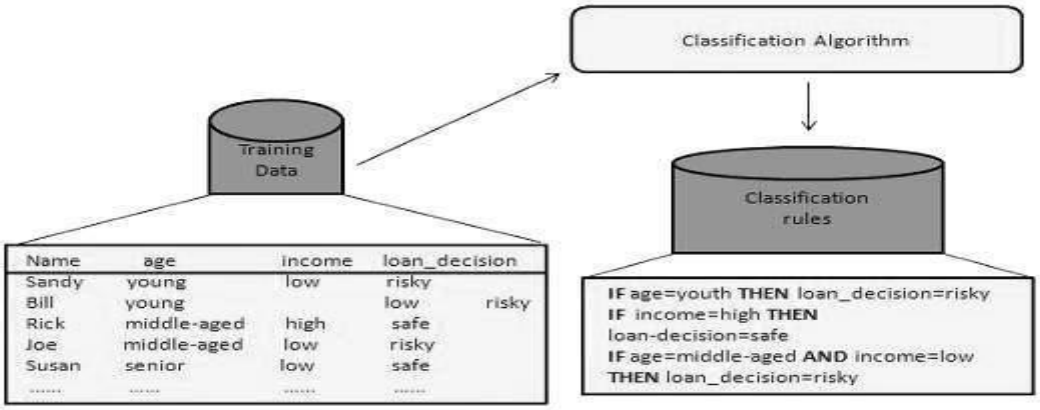
How Does Classification Works?

With the help of the bank loan application that we have discussed above, let us understand the working of classification. The Data Classification process includes two steps −

- Building the Classifier or Model
- Using Classifier for Classification

Building the Classifier or Model

- This step is the learning step or the learning phase.
- In this step the classification algorithms build the classifier.
- The classifier is built from the training set made up of database tuples and their associated class labels.
- Each tuple that constitutes the training set is referred to as a category or class. These tuples can also be referred to as sample, object or data points.

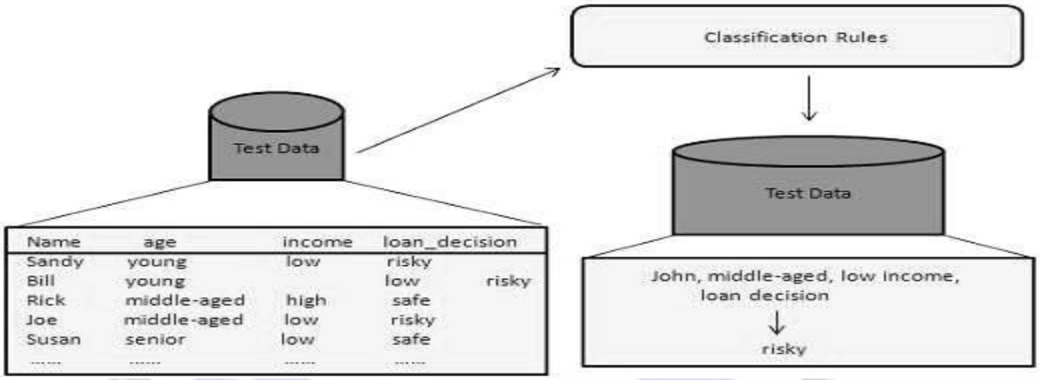


Name	age	income	loan_decision	
Sandy	young	low	risky	
Bill	young		low	risky
Rick	middle-aged	high	safe	
Joe	middle-aged	low	risky	
Susan	senior	low	safe	
......	......	......	......	

IF age=youth **THEN** loan_decision=risky
IF income=high **THEN**
loan-decision=safe
IF age=middle-aged **AND** income=low
THEN loan_decision=risky

Using Classifier for Classification

In this step, the classifier is used for classification. Here the test data is used to estimate the accuracy of classification rules. The classification rules can be applied to the new data tuples if the accuracy is considered acceptable.



Name	age	income	loan_decision	
Sandy	young	low	risky	
Bill	young		low	risky
Rick	middle-aged	high	safe	
Joe	middle-aged	low	risky	
Susan	senior	low	safe	
......	......	......	......	

Classification and Prediction Issues

The major issue is preparing the data for Classification and Prediction. Preparing the data involves the following activities −

- **Data Cleaning** − Data cleaning involves removing the noise and treatment of missing values. The noise is removed by applying smoothing techniques and the problem of missing values is solved by replacing a missing value with most commonly occurring value for that attribute.
- **Relevance Analysis** − Database may also have the irrelevant attributes. Correlation analysis is used to know whether any two given attributes are related.
- **Data Transformation and reduction** − The data can be transformed by any of the following methods.
  - **Normalization** − The data is transformed using normalization. Normalization involves scaling all values for given attribute in order to make them fall within a small specified range. Normalization is used when in the learning step, the neural networks or the methods involving measurements are used.
  - **Generalization** − The data can also be transformed by generalizing it to the higher concept. For this purpose we can use the concept hierarchies.

Note − Data can also be reduced by some other methods such as wavelet transformation, binning, histogram analysis, and clustering.

Comparison of Classification and Prediction Methods

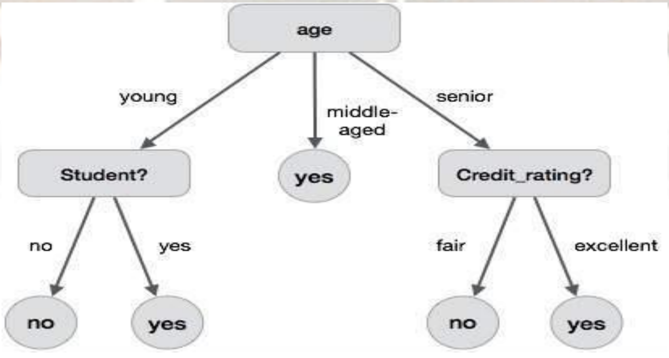
Here is the criteria for comparing the methods of Classification and Prediction −

- **Accuracy** − Accuracy of classifier refers to the ability of classifier. It predict the class label correctly and the accuracy of the predictor refers to how well a given predictor can guess the value of predicted attribute for a new data.
- **Speed** − This refers to the computational cost in generating and using the classifier or predictor.
- **Robustness** − It refers to the ability of classifier or predictor to make correct predictions from given noisy data.
- **Scalability** − Scalability refers to the ability to construct the classifier or predictor efficiently; given large amount of data.
- **Interpretability** − It refers to what extent the classifier or predictor understands.

Data Mining - Decision Tree Induction

A decision tree is a structure that includes a root node, branches, and leaf nodes. Each internal node denotes a test on an attribute, each branch denotes the outcome of a test, and each leaf node holds a class label. The topmost node in the tree is the root node.

The following decision tree is for the concept buy_computer that indicates whether a customer at a company is likely to buy a computer or not. Each internal node represents a test on an attribute. Each leaf node represents a class.



The benefits of having a decision tree are as follows −

- It does not require any domain knowledge.
- It is easy to comprehend.
- The learning and classification steps of a decision tree are simple and fast.

Decision Tree Induction Algorithm

A machine researcher named J. Ross Quinlan in 1980 developed a decision tree algorithm known as ID3 (Iterative Dichotomiser). Later, he presented C4.5, which was the successor of ID3. ID3 and C4.5 adopt a greedy approach. In this algorithm, there is no backtracking; the trees are constructed in a top-down recursive divide-and-conquer manner.

```
Generating a decision tree form training tuples of data partition D
Algorithm : Generate_decision_tree

Input:
Data partition, D, which is a set of training tuples
and their associated class labels.
attribute_list, the set of candidate attributes.
Attribute selection method, a procedure to determine the
splitting criterion that best partitions that the data
tuples into individual classes. This criterion includes a
splitting_attribute and either a splitting point or splitting subset.

Output:
 A Decision Tree

Method
create a node N;

if tuples in D are all of the same class, C then
   return N as leaf node labeled with class C;

if attribute_list is empty then
   return N as leaf node with labeled
   with majority class in D;|| majority voting

apply attribute_selection_method(D, attribute_list)
to find the best splitting_criterion;
label node N with splitting_criterion;
```

```
if splitting_attribute is discrete-valued and
   multiway splits allowed then  // no restricted to binary trees

attribute_list = splitting attribute; // remove splitting attribute
for each outcome j of splitting criterion

   // partition the tuples and grow subtrees for each partition
   let Dj be the set of data tuples in D satisfying outcome j; // a partition

   if Dj is empty then
      attach a leaf labeled with the majority
      class in D to node N;
   else
      attach the node returned by Generate
      decision tree(Dj, attribute list) to node N;
   end for
return N;
```

Tree Pruning

Tree pruning is performed in order to remove anomalies in the training data due to noise or outliers. The pruned trees are smaller and less complex.

Tree Pruning Approaches

There are two approaches to prune a tree −

- **Pre-pruning** − The tree is pruned by halting its construction early.
- **Post-pruning** - This approach removes a sub-tree from a fully grown tree.

Cost Complexity

The cost complexity is measured by the following two parameters −

- Number of leaves in the tree, and
- Error rate of the tree.

Data Mining - Bayesian Classification

Bayesian classification is based on Bayes' Theorem. Bayesian classifiers are the statistical classifiers. Bayesian classifiers can predict class membership probabilities such as the probability that a given tuple belongs to a particular class.

Baye's Theorem

Bayes' Theorem is named after Thomas Bayes. There are two types of probabilities −

- Posterior Probability [P(H/X)]
- Prior Probability [P(H)]

where X is data tuple and H is some hypothesis.

According to Bayes' Theorem,

$$P(H/X)= P(X/H)P(H) / P(X)$$

Bayesian Belief Network

Bayesian Belief Networks specify joint conditional probability distributions. They are also known as Belief Networks, Bayesian Networks, or Probabilistic Networks.

- A Belief Network allows class conditional independencies to be defined between subsets of variables.
- It provides a graphical model of causal relationship on which learning can be performed.
- We can use a trained Bayesian Network for classification.

There are two components that define a Bayesian Belief Network −

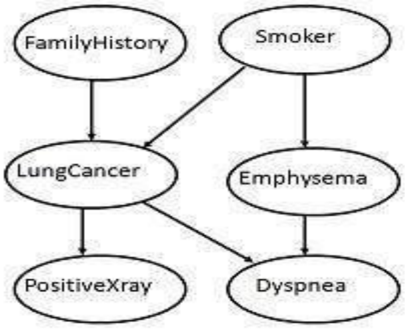
- Directed acyclic graph
- A set of conditional probability tables

Directed Acyclic Graph

- Each node in a directed acyclic graph represents a random variable.
- These variable may be discrete or continuous valued.
- These variables may correspond to the actual attribute given in the data.

Directed Acyclic Graph Representation

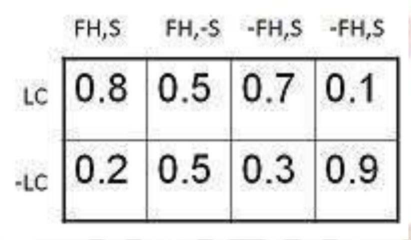
The following diagram shows a directed acyclic graph for six Boolean variables.



The arc in the diagram allows representation of causal knowledge. For example, lung cancer is influenced by a person's family history of lung cancer, as well as whether or not the person is a smoker. It is worth noting that the variable PositiveXray is independent of whether the patient has a family history of lung cancer or that the patient is a smoker, given that we know the patient has lung cancer.

Conditional Probability Table

The conditional probability table for the values of the variable LungCancer (LC) showing each possible combination of the values of its parent nodes, FamilyHistory (FH), and Smoker (S) is as follows −



	FH,S	FH,-S	-FH,S	-FH,S
LC	0.8	0.5	0.7	0.1
-LC	0.2	0.5	0.3	0.9

Data Mining - Rule Based Classification

IF-THEN Rules

Rule-based classifier makes use of a set of IF-THEN rules for classification. We can express a rule in the following from −

IF condition THEN conclusion

Let us consider a rule R1,

```
R1: IF age = youth AND student = yes
  THEN buy_computer = yes
```

Points to remember −

- The IF part of the rule is called **rule antecedent** or **precondition**.
- The THEN part of the rule is called **rule consequent**.
- The antecedent part the condition consist of one or more attribute tests and these tests are logically ANDed.
- The consequent part consists of class prediction.

Note − We can also write rule R1 as follows −

```
R1: (age = youth) ^ (student = yes))(buys computer = yes)
```

If the condition holds true for a given tuple, then the antecedent is satisfied.

Rule Extraction

Here we will learn how to build a rule-based classifier by extracting IF-THEN rules from a decision tree.

Points to remember −

To extract a rule from a decision tree −

- One rule is created for each path from the root to the leaf node.
- To form a rule antecedent, each splitting criterion is logically ANDed.

- The leaf node holds the class prediction, forming the rule consequent.

Rule Induction Using Sequential Covering Algorithm

Sequential Covering Algorithm can be used to extract IF-THEN rules form the training data. We do not require to generate a decision tree first. In this algorithm, each rule for a given class covers many of the tuples of that class.

Some of the sequential Covering Algorithms are AQ, CN2, and RIPPER. As per the general strategy the rules are learned one at a time. For each time rules are learned, a tuple covered by the rule is removed and the process continues for the rest of the tuples. This is because the path to each leaf in a decision tree corresponds to a rule.

Note − The Decision tree induction can be considered as learning a set of rules simultaneously.

The Following is the sequential learning Algorithm where rules are learned for one class at a time. When learning a rule from a class Ci, we want the rule to cover all the tuples from class C only and no tuple form any other class.

```
Algorithm: Sequential Covering

Input:
D, a data set class-labeled tuples,
Att_vals, the set of all attributes and their possible values.

Output:  A Set of IF-THEN rules.
Method:
Rule_set={ }; // initial set of rules learned is empty

for each class c do

   repeat
      Rule = Learn_One_Rule(D, Att_valls, c);
      remove tuples covered by Rule form D;
   until termination condition;

   Rule_set=Rule_set+Rule; // add a new rule to rule-set
end for
return Rule_Set;
```

Rule Pruning

The rule is pruned is due to the following reason −

- The Assessment of quality is made on the original set of training data. The rule may perform well on training data but less well on subsequent data. That's why the rule pruning is required.
- The rule is pruned by removing conjunct. The rule R is pruned, if pruned version of R has greater quality than what was assessed on an independent set of tuples.

FOIL is one of the simple and effective method for rule pruning. For a given rule R,

$$FOIL\_Prune = pos - neg / pos + neg$$

where pos and neg is the number of positive tuples covered by R, respectively.

Note − This value will increase with the accuracy of R on the pruning set. Hence, if the FOIL_Prune value is higher for the pruned version of R, then we prune R.

Miscellaneous Classification Methods

Here we will discuss other classification methods such as Genetic Algorithms, Rough Set Approach, and Fuzzy Set Approach.

Genetic Algorithms

The idea of genetic algorithm is derived from natural evolution. In genetic algorithm, first of all, the initial population is created. This initial population consists of randomly generated rules. We can represent each rule by a string of bits.

For example, in a given training set, the samples are described by two Boolean attributes such as A1 and A2. And this given training set contains two classes such as C1 and C2.

We can encode the rule **IF A1 AND NOT A2 THEN C2** into a bit string **100**. In this bit representation, the two leftmost bits represent the attribute A1 and A2, respectively.

Likewise, the rule **IF NOT A1 AND NOT A2 THEN C1** can be encoded as **001**.

Note − If the attribute has K values where K>2, then we can use the K bits to encode the attribute values. The classes are also encoded in the same manner.

Points to remember −

- Based on the notion of the survival of the fittest, a new population is formed that consists of the fittest rules in the current population and offspring values of these rules as well.

- The fitness of a rule is assessed by its classification accuracy on a set of training samples.
- The genetic operators such as crossover and mutation are applied to create offspring.
- In crossover, the substring from pair of rules are swapped to form a new pair of rules.
- In mutation, randomly selected bits in a rule's string are inverted.

Rough Set Approach

We can use the rough set approach to discover structural relationship within imprecise and noisy data.

Note − This approach can only be applied on discrete-valued attributes. Therefore, continuous-valued attributes must be discretized before its use.

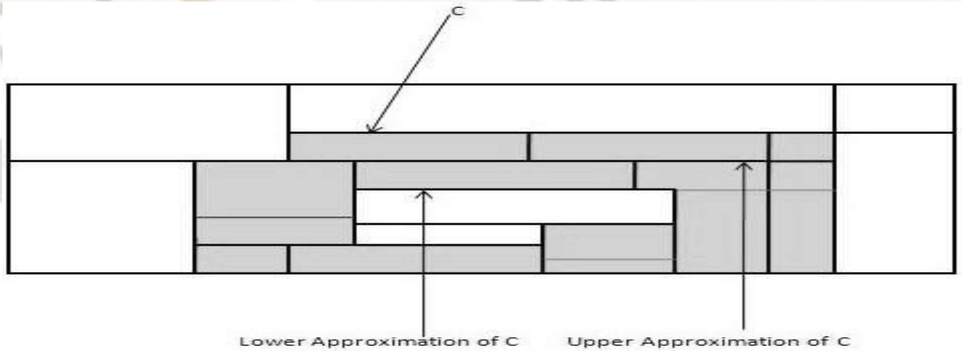
The Rough Set Theory is based on the establishment of equivalence classes within the given training data. The tuples that forms the equivalence class are indiscernible. It means the samples are identical with respect to the attributes describing the data.

There are some classes in the given real world data, which cannot be distinguished in terms of available attributes. We can use the rough sets to **roughly** define such classes.

For a given class C, the rough set definition is approximated by two sets as follows −

- **Lower Approximation of C** − The lower approximation of C consists of all the data tuples, that based on the knowledge of the attribute, are certain to belong to class C.
- **Upper Approximation of C** − The upper approximation of C consists of all the tuples, that based on the knowledge of attributes, cannot be described as not belonging to C.

The following diagram shows the Upper and Lower Approximation of class C −



Fuzzy Set Approaches

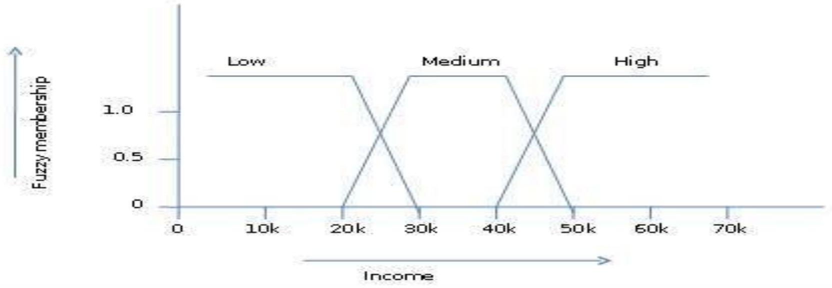
Fuzzy Set Theory is also called Possibility Theory. This theory was proposed by Lotfi Zadeh in 1965 as an alternative the **two-value logic** and **probability theory**. This theory allows us to work at a high level of abstraction. It also provides us the means for dealing with imprecise measurement of data.

The fuzzy set theory also allows us to deal with vague or inexact facts. For example, being a member of a set of high incomes is in exact (e.g. if $50,000 is high then what about $49,000 and $48,000). Unlike the traditional CRISP set where the element either belong to S or its complement but in fuzzy set theory the element can belong to more than one fuzzy set.

For example, the income value $49,000 belongs to both the medium and high fuzzy sets but to differing degrees. Fuzzy set notation for this income value is as follows −

$m_{medium\_income}(\$49k)=0.15$ and $m_{high\_income}(\$49k)=0.96$

where 'm' is the membership function that operates on the fuzzy sets of medium_income and high_income respectively. This notation can be shown diagrammatically as follows −



Data Mining - Cluster Analysis

Cluster is a group of objects that belongs to the same class. In other words, similar objects are grouped in one cluster and dissimilar objects are grouped in another cluster.

What is Clustering?

Clustering is the process of making a group of abstract objects into classes of similar objects.

Points to Remember

- A cluster of data objects can be treated as one group.

- While doing cluster analysis, we first partition the set of data into groups based on data similarity and then assign the labels to the groups.
- The main advantage of clustering over classification is that, it is adaptable to changes and helps single out useful features that distinguish different groups.

Applications of Cluster Analysis

- Clustering analysis is broadly used in many applications such as market research, pattern recognition, data analysis, and image processing.
- Clustering can also help marketers discover distinct groups in their customer base. And they can characterize their customer groups based on the purchasing patterns.
- In the field of biology, it can be used to derive plant and animal taxonomies, categorize genes with similar functionalities and gain insight into structures inherent to populations.
- Clustering also helps in identification of areas of similar land use in an earth observation database. It also helps in the identification of groups of houses in a city according to house type, value, and geographic location.
- Clustering also helps in classifying documents on the web for information discovery.
- Clustering is also used in outlier detection applications such as detection of credit card fraud.
- As a data mining function, cluster analysis serves as a tool to gain insight into the distribution of data to observe characteristics of each cluster.

Requirements of Clustering in Data Mining

The following points throw light on why clustering is required in data mining −

- **Scalability** − We need highly scalable clustering algorithms to deal with large databases.
- **Ability to deal with different kinds of attributes** − Algorithms should be capable to be applied on any kind of data such as interval-based (numerical) data, categorical, and binary data.

- **Discovery of clusters with attribute shape** − The clustering algorithm should be capable of detecting clusters of arbitrary shape. They should not be bounded to only distance measures that tend to find spherical cluster of small sizes.
- **High dimensionality** − The clustering algorithm should not only be able to handle low-dimensional data but also the high dimensional space.
- **Ability to deal with noisy data** − Databases contain noisy, missing or erroneous data. Some algorithms are sensitive to such data and may lead to poor quality clusters.
- **Interpretability** − The clustering results should be interpretable, comprehensible, and usable.

Clustering Methods

Clustering methods can be classified into the following categories −

- Partitioning Method
- Hierarchical Method
- Density-based Method
- Grid-Based Method
- Model-Based Method
- Constraint-based Method

Partitioning Method

Suppose we are given a database of 'n' objects and the partitioning method constructs 'k' partition of data. Each partition will represent a cluster and k ≤ n. It means that it will classify the data into k groups, which satisfy the following requirements −

- Each group contains at least one object.
- Each object must belong to exactly one group.

Points to remember −

- For a given number of partitions (say k), the partitioning method will create an initial partitioning.

- Then it uses the iterative relocation technique to improve the partitioning by moving objects from one group to other.

Hierarchical Methods

This method creates a hierarchical decomposition of the given set of data objects. We can classify hierarchical methods on the basis of how the hierarchical decomposition is formed. There are two approaches here −

- Agglomerative Approach
- Divisive Approach

Agglomerative Approach

This approach is also known as the bottom-up approach. In this, we start with each object forming a separate group. It keeps on merging the objects or groups that are close to one another. It keep on doing so until all of the groups are merged into one or until the termination condition holds.

Divisive Approach

This approach is also known as the top-down approach. In this, we start with all of the objects in the same cluster. In the continuous iteration, a cluster is split up into smaller clusters. It is down until each object in one cluster or the termination condition holds. This method is rigid, i.e., once a merging or splitting is done, it can never be undone.

Approaches to Improve Quality of Hierarchical Clustering

Here are the two approaches that are used to improve the quality of hierarchical clustering −

- Perform careful analysis of object linkages at each hierarchical partitioning.
- Integrate hierarchical agglomeration by first using a hierarchical agglomerative algorithm to group objects into micro-clusters, and then performing macro-clustering on the micro-clusters.

Density-based Method

This method is based on the notion of density. The basic idea is to continue growing the given cluster as long as the density in the neighborhood exceeds some threshold, i.e., for each data point within a given cluster, the radius of a given cluster has to contain at least a minimum number of points.

Grid-based Method

In this, the objects together form a grid. The object space is quantized into finite number of cells that form a grid structure.

Advantage

- The major advantage of this method is fast processing time.
- It is dependent only on the number of cells in each dimension in the quantized space.

Model-based methods

In this method, a model is hypothesized for each cluster to find the best fit of data for a given model. This method locates the clusters by clustering the density function. It reflects spatial distribution of the data points.

This method also provides a way to automatically determine the number of clusters based on standard statistics, taking outlier or noise into account. It therefore yields robust clustering methods.

Constraint-based Method

In this method, the clustering is performed by the incorporation of user or application-oriented constraints. A constraint refers to the user expectation or the properties of desired clustering results. Constraints provide us with an interactive way of communication with the clustering process. Constraints can be specified by the user or the application requirement.

Data Mining - Mining Text Data

Text databases consist of huge collection of documents. They collect these information from several sources such as news articles, books, digital libraries, e-mail messages, web pages, etc. Due to increase in the amount of information, the text databases are growing rapidly. In many of the text databases, the data is semi-structured.

For example, a document may contain a few structured fields, such as title, author, publishing_date, etc. But along with the structure data, the document also contains unstructured text components, such as abstract and contents. Without knowing what could be in the documents, it is difficult to formulate effective queries for analyzing and extracting useful information from the data. Users require tools to compare the documents and rank their importance and relevance. Therefore, text mining has become popular and an essential theme in data mining.

Information Retrieval

Information retrieval deals with the retrieval of information from a large number of text-based documents. Some of the database systems are not usually present in information retrieval systems because both handle different kinds of data. Examples of information retrieval system include −

- Online Library catalogue system
- Online Document Management Systems
- Web Search Systems etc.

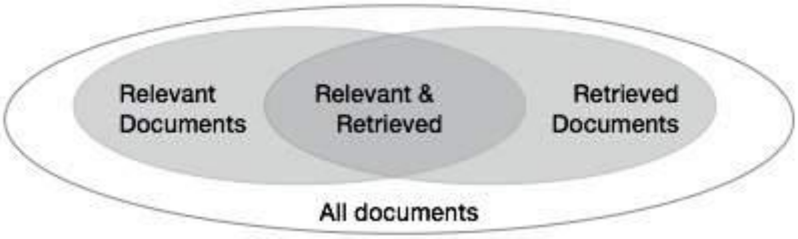
Note − The main problem in an information retrieval system is to locate relevant documents in a document collection based on a user's query. This kind of user's query consists of some keywords describing an information need.

In such search problems, the user takes an initiative to pull relevant information out from a collection. This is appropriate when the user has ad-hoc information need, i.e., a short-term need. But if the user has a long-term information need, then the retrieval system can also take an initiative to push any newly arrived information item to the user.

This kind of access to information is called Information Filtering. And the corresponding systems are known as Filtering Systems or Recommender Systems.

Basic Measures for Text Retrieval

We need to check the accuracy of a system when it retrieves a number of documents on the basis of user's input. Let the set of documents relevant to a query be denoted as {Relevant} and the set of retrieved document as {Retrieved}. The set of documents that are relevant and retrieved can be denoted as {Relevant} ∩ {Retrieved}. This can be shown in the form of a Venn diagram as follows −



There are three fundamental measures for assessing the quality of text retrieval −

- Precision
- Recall
- F-score

Precision

Precision is the percentage of retrieved documents that are in fact relevant to the query. Precision can be defined as −

Precision= |{Relevant} ∩ {Retrieved}| / |{Retrieved}|

Recall

Recall is the percentage of documents that are relevant to the query and were in fact retrieved. Recall is defined as −

Recall = |{Relevant} ∩ {Retrieved}| / |{Relevant}|

F-score

F-score is the commonly used trade-off. The information retrieval system often needs to trade-off for precision or vice versa. F-score is defined as harmonic mean of recall or precision as follows −

F-score = recall x precision / (recall + precision) / 2

Data Mining - Mining World Wide Web

The World Wide Web contains huge amounts of information that provides a rich source for data mining.

Challenges in Web Mining

The web poses great challenges for resource and knowledge discovery based on the following observations −

- **The web is too huge** − The size of the web is very huge and rapidly increasing. This seems that the web is too huge for data warehousing and data mining.
- **Complexity of Web pages** − The web pages do not have unifying structure. They are very complex as compared to traditional text document. There are huge amount of documents in digital library of web. These libraries are not arranged according to any particular sorted order.
- **Web is dynamic information source** − The information on the web is rapidly updated. The data such as news, stock markets, weather, sports, shopping, etc., are regularly updated.
- **Diversity of user communities** − The user community on the web is rapidly expanding. These users have different backgrounds, interests, and usage purposes. There are more than 100 million workstations that are connected to the Internet and still rapidly increasing.
- **Relevancy of Information** − It is considered that a particular person is generally interested in only small portion of the web, while the rest of the portion of the web contains the information that is not relevant to the user and may swamp desired results.

Mining Web page layout structure

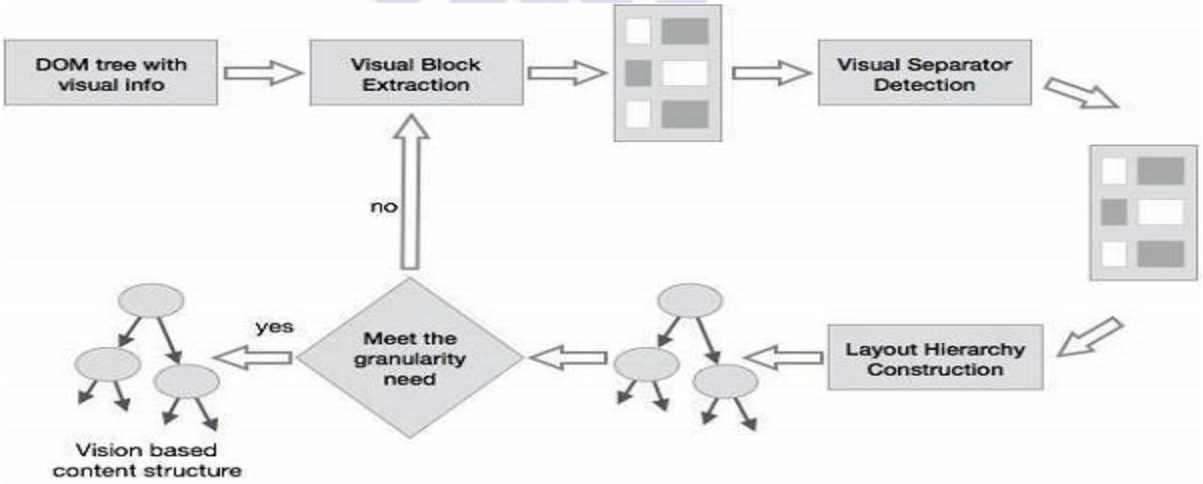
The basic structure of the web page is based on the Document Object Model (DOM). The DOM structure refers to a tree like structure where the HTML tag in the page corresponds to a node in the DOM tree. We can segment the web page by using predefined tags in HTML. The HTML syntax is flexible therefore, the web pages does not follow the W3C specifications. Not following the specifications of W3C may cause error in DOM tree structure.

The DOM structure was initially introduced for presentation in the browser and not for description of semantic structure of the web page. The DOM structure cannot correctly identify the semantic relationship between the different parts of a web page.

Vision-based page segmentation (VIPS)

- The purpose of VIPS is to extract the semantic structure of a web page based on its visual presentation.
- Such a semantic structure corresponds to a tree structure. In this tree each node corresponds to a block.
- A value is assigned to each node. This value is called the Degree of Coherence. This value is assigned to indicate the coherent content in the block based on visual perception.
- The VIPS algorithm first extracts all the suitable blocks from the HTML DOM tree. After that it finds the separators between these blocks.
- The separators refer to the horizontal or vertical lines in a web page that visually cross with no blocks.
- The semantics of the web page is constructed on the basis of these blocks.

The following figure shows the procedure of VIPS algorithm −


DOM tree with visual info
Visual Block Extraction
Visual Separator Detection
no
yes
Meet the granularity need
Layout Hierarchy Construction
Vision based content structure

Data Mining - Applications & Trends

Data mining is widely used in diverse areas. There are a number of commercial data mining system available today and yet there are many challenges in this field. In this tutorial, we will discuss the applications and the trend of data mining.

Data Mining Applications

Here is the list of areas where data mining is widely used −

- Financial Data Analysis
- Retail Industry
- Telecommunication Industry
- Biological Data Analysis
- Other Scientific Applications
- Intrusion Detection

Financial Data Analysis

The financial data in banking and financial industry is generally reliable and of high quality which facilitates systematic data analysis and data mining. Some of the typical cases are as follows −

- Design and construction of data warehouses for multidimensional data analysis and data mining.
- Loan payment prediction and customer credit policy analysis.
- Classification and clustering of customers for targeted marketing.
- Detection of money laundering and other financial crimes.

Retail Industry

Data Mining has its great application in Retail Industry because it collects large amount of data from on sales, customer purchasing history, goods transportation, consumption and services. It is natural that the quantity of data collected will continue to expand rapidly because of the increasing ease, availability and popularity of the web.

Data mining in retail industry helps in identifying customer buying patterns and trends that lead to improved quality of customer service and good customer retention and satisfaction. Here is the list of examples of data mining in the retail industry −

- Design and Construction of data warehouses based on the benefits of data mining.
- Multidimensional analysis of sales, customers, products, time and region.
- Analysis of effectiveness of sales campaigns.
- Customer Retention.
- Product recommendation and cross-referencing of items.

Telecommunication Industry

Today the telecommunication industry is one of the most emerging industries providing various services such as fax, pager, cellular phone, internet messenger, images, e-mail, web data transmission, etc. Due to the development of new computer and communication technologies, the telecommunication industry is rapidly expanding. This is the reason why data mining is become very important to help and understand the business.

Data mining in telecommunication industry helps in identifying the telecommunication patterns, catch fraudulent activities, make better use of resource, and improve quality of service. Here is the list of examples for which data mining improves telecommunication services −

- Multidimensional Analysis of Telecommunication data.
- Fraudulent pattern analysis.
- Identification of unusual patterns.
- Multidimensional association and sequential patterns analysis.
- Mobile Telecommunication services.
- Use of visualization tools in telecommunication data analysis.

Biological Data Analysis

In recent times, we have seen a tremendous growth in the field of biology such as genomics, proteomics, functional Genomics and biomedical research. Biological data mining is a very important part of Bioinformatics. Following are the aspects in which data mining contributes for biological data analysis −

- Semantic integration of heterogeneous, distributed genomic and proteomic databases.
- Alignment, indexing, similarity search and comparative analysis multiple nucleotide sequences.
- Discovery of structural patterns and analysis of genetic networks and protein pathways.
- Association and path analysis.
- Visualization tools in genetic data analysis.

Other Scientific Applications

The applications discussed above tend to handle relatively small and homogeneous data sets for which the statistical techniques are appropriate. Huge amount of data have been collected from scientific domains such as geosciences, astronomy, etc. A large amount of data sets is being generated because of the fast numerical simulations in various fields such as climate and ecosystem modeling, chemical engineering, fluid dynamics, etc. Following are the applications of data mining in the field of Scientific Applications −

- Data Warehouses and data preprocessing.
- Graph-based mining.
- Visualization and domain specific knowledge.

Intrusion Detection

Intrusion refers to any kind of action that threatens integrity, confidentiality, or the availability of network resources. In this world of connectivity, security has become the major issue. With increased usage of internet and availability of the tools and tricks for intruding and attacking network prompted intrusion detection to become a critical component of network administration. Here is the list of areas in which data mining technology may be applied for intrusion detection −

- Development of data mining algorithm for intrusion detection.
- Association and correlation analysis, aggregation to help select and build discriminating attributes.

- Analysis of Stream data.
- Distributed data mining.
- Visualization and query tools.

Data Mining System Products

There are many data mining system products and domain specific data mining applications. The new data mining systems and applications are being added to the previous systems. Also, efforts are being made to standardize data mining languages.

Choosing a Data Mining System

The selection of a data mining system depends on the following features −

- **Data Types** − The data mining system may handle formatted text, record-based data, and relational data. The data could also be in ASCII text, relational database data or data warehouse data. Therefore, we should check what exact format the data mining system can handle.
- **System Issues** − We must consider the compatibility of a data mining system with different operating systems. One data mining system may run on only one operating system or on several. There are also data mining systems that provide web-based user interfaces and allow XML data as input.
- **Data Sources** − Data sources refer to the data formats in which data mining system will operate. Some data mining system may work only on ASCII text files while others on multiple relational sources. Data mining system should also support ODBC connections or OLE DB for ODBC connections.
- **Data Mining functions and methodologies** − There are some data mining systems that provide only one data mining function such as classification while some provides multiple data mining functions such as concept description, discovery-driven OLAP analysis, association mining, linkage analysis, statistical analysis, classification, prediction, clustering, outlier analysis, similarity search, etc.
- **Coupling data mining with databases or data warehouse systems** − Data mining systems need to be coupled with a database or a data warehouse system. The coupled

components are integrated into a uniform information processing environment. Here are the types of coupling listed below −

- No coupling
- Loose Coupling
- Semi tight Coupling
- Tight Coupling

- **Scalability** − There are two scalability issues in data mining −
  - **Row (Database size) Scalability** − A data mining system is considered as row scalable when the number or rows are enlarged 10 times. It takes no more than 10 times to execute a query.
  - **Column (Dimension) Salability** − A data mining system is considered as column scalable if the mining query execution time increases linearly with the number of columns.
- **Visualization Tools** − Visualization in data mining can be categorized as follows −
  - Data Visualization
  - Mining Results Visualization
  - Mining process visualization
  - Visual data mining
- **Data Mining query language and graphical user interface** − An easy-to-use graphical user interface is important to promote user-guided, interactive data mining. Unlike relational database systems, data mining systems do not share underlying data mining query language.

Trends in Data Mining

Data mining concepts are still evolving and here are the latest trends that we get to see in this field −

- Application Exploration.
- Scalable and interactive data mining methods.

- Integration of data mining with database systems, data warehouse systems and web database systems.
- SStandardization of data mining query language.
- Visual data mining.
- New methods for mining complex types of data.
- Biological data mining.
- Data mining and software engineering.
- Web mining.
- Distributed data mining.
- Real time data mining.
- Multi database data mining.
- Privacy protection and information security in data mining.

Data Mining - Themes

Theoretical Foundations of Data Mining

The theoretical foundations of data mining includes the following concepts −

- **Data Reduction** − The basic idea of this theory is to reduce the data representation which trades accuracy for speed in response to the need to obtain quick approximate answers to queries on very large databases. Some of the data reduction techniques are as follows −
    - Singular value Decomposition
    - Wavelets
    - Regression
    - Log-linear models
    - Histograms
    - Clustering
    - Sampling
    - Construction of Index Trees

- **Data Compression** – The basic idea of this theory is to compress the given data by encoding in terms of the following –
  - Bits
  - Association Rules
  - Decision Trees
  - Clusters
- **Pattern Discovery** – The basic idea of this theory is to discover patterns occurring in a database. Following are the areas that contribute to this theory –
  - Machine Learning
  - Neural Network
  - Association Mining
  - Sequential Pattern Matching
  - Clustering
- **Probability Theory** – This theory is based on statistical theory. The basic idea behind this theory is to discover joint probability distributions of random variables.
- **Probability Theory** – According to this theory, data mining finds the patterns that are interesting only to the extent that they can be used in the decision-making process of some enterprise.
- **Microeconomic View** – As per this theory, a database schema consists of data and patterns that are stored in a database. Therefore, data mining is the task of performing induction on databases.
- **Inductive databases** – Apart from the database-oriented techniques, there are statistical techniques available for data analysis. These techniques can be applied to scientific data and data from economic and social sciences as well.

Statistical Data Mining

Some of the Statistical Data Mining Techniques are as follows –

- **Regression** − Regression methods are used to predict the value of the response variable from one or more predictor variables where the variables are numeric. Listed below are the forms of Regression −
  - Linear
  - Multiple
  - Weighted
  - Polynomial
  - Nonparametric
  - Robust
- **Generalized Linear Models** − Generalized Linear Model includes −
  - Logistic Regression
  - Poisson Regression

  The model's generalization allows a categorical response variable to be related to a set of predictor variables in a manner similar to the modelling of numeric response variable using linear regression.
- **Analysis of Variance** − This technique analyzes −
  - Experimental data for two or more populations described by a numeric response variable.
  - One or more categorical variables (factors).
- **Mixed-effect Models** − These models are used for analyzing grouped data. These models describe the relationship between a response variable and some co-variates in the data grouped according to one or more factors.
- **Factor Analysis** − Factor analysis is used to predict a categorical response variable. This method assumes that independent variables follow a multivariate normal distribution.
- **Time Series Analysis** − Following are the methods for analyzing time-series data −
  - Auto-regression Methods.

  - Univariate ARIMA (AutoRegressive Integrated Moving Average) Modeling.
  - Long-memory time-series modeling.

Visual Data Mining

Visual Data Mining uses data and/or knowledge visualization techniques to discover implicit knowledge from large data sets. Visual data mining can be viewed as an integration of the following disciplines −

- Data Visualization
- Data Mining

Visual data mining is closely related to the following −

- Computer Graphics
- Multimedia Systems
- Human Computer Interaction
- Pattern Recognition
- High-performance Computing

Generally data visualization and data mining can be integrated in the following ways −

- **Data Visualization** − The data in a database or a data warehouse can be viewed in several visual forms that are listed below −
  - Boxplots
  - 3-D Cubes
  - Data distribution charts
  - Curves
  - Surfaces
  - Link graphs etc.

- **Data Mining Result Visualization** − Data Mining Result Visualization is the presentation of the results of data mining in visual forms. These visual forms could be scattered plots, boxplots, etc.
- **Data Mining Process Visualization** − Data Mining Process Visualization presents the several processes of data mining. It allows the users to see how the data is extracted. It also allows the users to see from which database or data warehouse the data is cleaned, integrated, preprocessed, and mined.

Audio Data Mining

Audio data mining makes use of audio signals to indicate the patterns of data or the features of data mining results. By transforming patterns into sound and musing, we can listen to pitches and tunes, instead of watching pictures, in order to identify anything interesting.

Data Mining and Collaborative Filtering

Consumers today come across a variety of goods and services while shopping. During live customer transactions, a Recommender System helps the consumer by making product recommendations. The Collaborative Filtering Approach is generally used for recommending products to customers. These recommendations are based on the opinions of other customers.

Data Mining - Quick Guide

There is a huge amount of data available in the Information Industry. This data is of no use until it is converted into useful information. It is necessary to analyze this huge amount of data and extract useful information from it.

Extraction of information is not the only process we need to perform; data mining also involves other processes such as Data Cleaning, Data Integration, Data Transformation, Data Mining, Pattern Evaluation and Data Presentation. Once all these processes are over, we would be able to use this information in many applications such as Fraud Detection, Market Analysis, Production Control, Science Exploration, etc.

What is Data Mining?

Data Mining is defined as extracting information from huge sets of data. In other words, we can say that data mining is the procedure of mining knowledge from data. The information or knowledge extracted so can be used for any of the following applications −

- Market Analysis
- Fraud Detection
- Customer Retention
- Production Control
- Science Exploration

Data Mining Applications

Data mining is highly useful in the following domains −

- Market Analysis and Management
- Corporate Analysis & Risk Management
- Fraud Detection

Apart from these, data mining can also be used in the areas of production control, customer retention, science exploration, sports, astrology, and Internet Web Surf-Aid

Market Analysis and Management

Listed below are the various fields of market where data mining is used −

- **Customer Profiling** − Data mining helps determine what kind of people buy what kind of products.
- **Identifying Customer Requirements** − Data mining helps in identifying the best products for different customers. It uses prediction to find the factors that may attract new customers.
- **Cross Market Analysis** − Data mining performs Association/correlations between product sales.
- **Target Marketing** − Data mining helps to find clusters of model customers who share the same characteristics such as interests, spending habits, income, etc.
- **Determining Customer purchasing pattern** − Data mining helps in determining customer purchasing pattern.

- **Providing Summary Information** − Data mining provides us various multidimensional summary reports.

Corporate Analysis and Risk Management

Data mining is used in the following fields of the Corporate Sector −

- **Finance Planning and Asset Evaluation** − It involves cash flow analysis and prediction, contingent claim analysis to evaluate assets.
- **Resource Planning** − It involves summarizing and comparing the resources and spending.
- **Competition** − It involves monitoring competitors and market directions.

Fraud Detection

Data mining is also used in the fields of credit card services and telecommunication to detect frauds. In fraud telephone calls, it helps to find the destination of the call, duration of the call, time of the day or week, etc. It also analyzes the patterns that deviate from expected norms.

Data Mining - Tasks

Data mining deals with the kind of patterns that can be mined. On the basis of the kind of data to be mined, there are two categories of functions involved in Data Mining −

- Descriptive
- Classification and Prediction

Descriptive Function

The descriptive function deals with the general properties of data in the database. Here is the list of descriptive functions −

- Class/Concept Description
- Mining of Frequent Patterns
- Mining of Associations
- Mining of Correlations
- Mining of Clusters

Class/Concept Description

Class/Concept refers to the data to be associated with the classes or concepts. For example, in a company, the classes of items for sales include computer and printers, and concepts of customers include big spenders and budget spenders. Such descriptions of a class or a concept are called class/concept descriptions. These descriptions can be derived by the following two ways −

- **Data Characterization** − This refers to summarizing data of class under study. This class under study is called as Target Class.
- **Data Discrimination** − It refers to the mapping or classification of a class with some predefined group or class.

Mining of Frequent Patterns

Frequent patterns are those patterns that occur frequently in transactional data. Here is the list of kind of frequent patterns −

- **Frequent Item Set** − It refers to a set of items that frequently appear together, for example, milk and bread.
- **Frequent Subsequence** − A sequence of patterns that occur frequently such as purchasing a camera is followed by memory card.
- **Frequent Sub Structure** − Substructure refers to different structural forms, such as graphs, trees, or lattices, which may be combined with item-sets or subsequences.

Mining of Association

Associations are used in retail sales to identify patterns that are frequently purchased together. This process refers to the process of uncovering the relationship among data and determining association rules.

For example, a retailer generates an association rule that shows that 70% of time milk is sold with bread and only 30% of times biscuits are sold with bread.

Mining of Correlations

It is a kind of additional analysis performed to uncover interesting statistical correlations between associated-attribute-value pairs or between two item sets to analyze that if they have positive, negative or no effect on each other.

Mining of Clusters

Cluster refers to a group of similar kind of objects. Cluster analysis refers to forming group of objects that are very similar to each other but are highly different from the objects in other clusters.

Classification and Prediction

Classification is the process of finding a model that describes the data classes or concepts. The purpose is to be able to use this model to predict the class of objects whose class label is unknown. This derived model is based on the analysis of sets of training data. The derived model can be presented in the following forms −

- Classification (IF-THEN) Rules
- Decision Trees
- Mathematical Formulae
- Neural Networks

The list of functions involved in these processes are as follows −

- **Classification** − It predicts the class of objects whose class label is unknown. Its objective is to find a derived model that describes and distinguishes data classes or concepts. The Derived Model is based on the analysis set of training data i.e. the data object whose class label is well known.
- **Prediction** − It is used to predict missing or unavailable numerical data values rather than class labels. Regression Analysis is generally used for prediction. Prediction can also be used for identification of distribution trends based on available data.
- **Outlier Analysis** − Outliers may be defined as the data objects that do not comply with the general behavior or model of the data available.
- **Evolution Analysis** − Evolution analysis refers to the description and model regularities or trends for objects whose behavior changes over time.

Data Mining Task Primitives

- We can specify a data mining task in the form of a data mining query.
- This query is input to the system.

- A data mining query is defined in terms of data mining task primitives.

Note − These primitives allow us to communicate in an interactive manner with the data mining system. Here is the list of Data Mining Task Primitives −

- Set of task relevant data to be mined.
- Kind of knowledge to be mined.
- Background knowledge to be used in discovery process.
- Interestingness measures and thresholds for pattern evaluation.
- Representation for visualizing the discovered patterns.

Set of task relevant data to be mined

This is the portion of database in which the user is interested. This portion includes the following −

- Database Attributes
- Data Warehouse dimensions of interest

Kind of knowledge to be mined

It refers to the kind of functions to be performed. These functions are −

- Characterization
- Discrimination
- Association and Correlation Analysis
- Classification
- Prediction
- Clustering
- Outlier Analysis
- Evolution Analysis

Background knowledge

The background knowledge allows data to be mined at multiple levels of abstraction. For example, the Concept hierarchies are one of the background knowledge that allows data to be mined at multiple levels of abstraction.

Interestingness measures and thresholds for pattern evaluation

This is used to evaluate the patterns that are discovered by the process of knowledge discovery. There are different interesting measures for different kind of knowledge.

Representation for visualizing the discovered patterns

This refers to the form in which discovered patterns are to be displayed. These representations may include the following. −

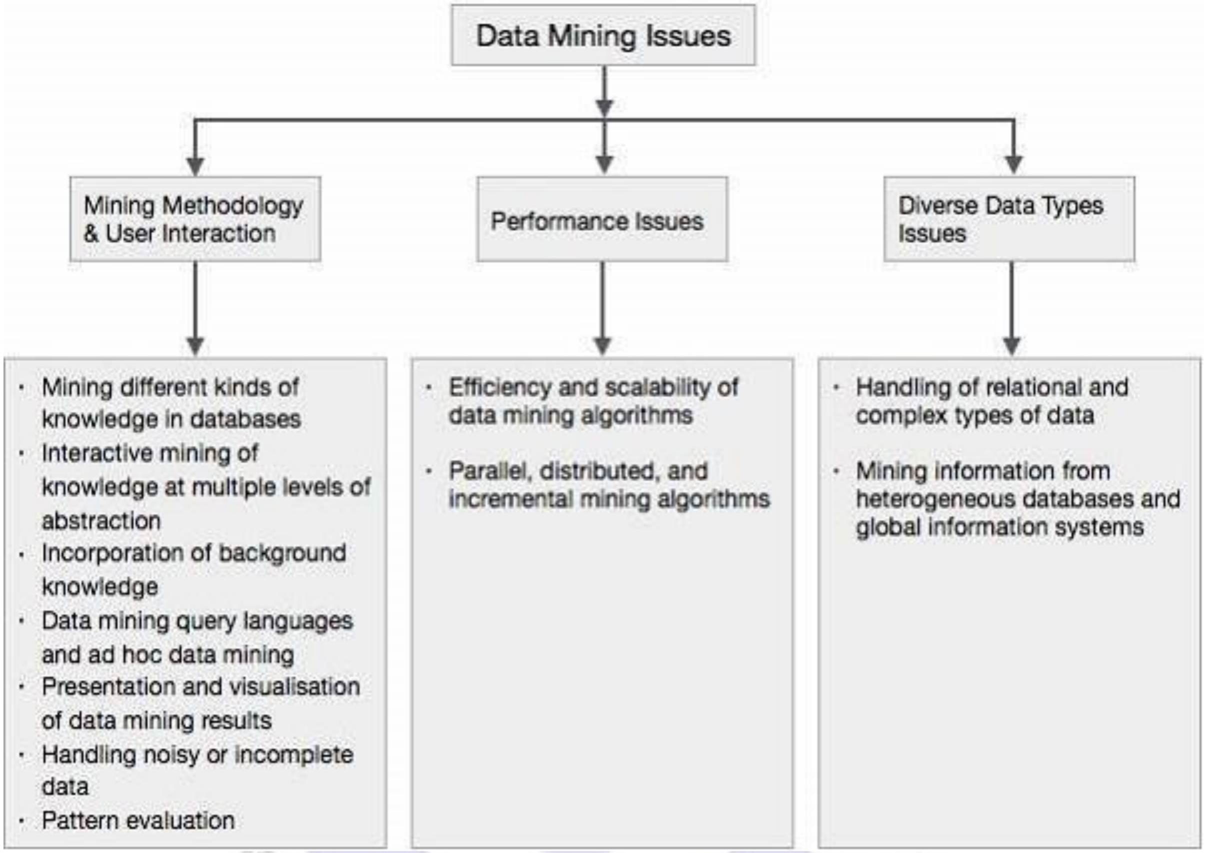
- Rules
- Tables
- Charts
- Graphs
- Decision Trees
- Cubes

Data Mining - Issues

Data mining is not an easy task, as the algorithms used can get very complex and data is not always available at one place. It needs to be integrated from various heterogeneous data sources. These factors also create some issues. Here in this tutorial, we will discuss the major issues regarding −

- Mining Methodology and User Interaction
- Performance Issues
- Diverse Data Types Issues

The following diagram describes the major issues.


Data Mining Issues
Mining Methodology & User Interaction
Performance Issues
Diverse Data Types Issues
Mining different kinds of knowledge in databases
Interactive mining of knowledge at multiple levels of abstraction
Incorporation of background knowledge
Data mining query languages and ad hoc data mining
Presentation and visualisation of data mining results
Handling noisy or incomplete data
Pattern evaluation
Efficiency and scalability of data mining algorithms
Parallel, distributed, and incremental mining algorithms
Handling of relational and complex types of data
Mining information from heterogeneous databases and global information systems

Mining Methodology and User Interaction Issues

It refers to the following kinds of issues −

- **Mining different kinds of knowledge in databases** − Different users may be interested in different kinds of knowledge. Therefore it is necessary for data mining to cover a broad range of knowledge discovery task.
- **Interactive mining of knowledge at multiple levels of abstraction** − The data mining process needs to be interactive because it allows users to focus the search for patterns, providing and refining data mining requests based on the returned results.
- **Incorporation of background knowledge** − To guide discovery process and to express the discovered patterns, the background knowledge can be used. Background knowledge may be used to express the discovered patterns not only in concise terms but at multiple levels of abstraction.

- **Data mining query languages and ad hoc data mining** − Data Mining Query language that allows the user to describe ad hoc mining tasks, should be integrated with a data warehouse query language and optimized for efficient and flexible data mining.
- **Presentation and visualization of data mining results** − Once the patterns are discovered it needs to be expressed in high level languages, and visual representations. These representations should be easily understandable.
- **Handling noisy or incomplete data** − The data cleaning methods are required to handle the noise and incomplete objects while mining the data regularities. If the data cleaning methods are not there then the accuracy of the discovered patterns will be poor.
- **Pattern evaluation** − The patterns discovered should be interesting because either they represent common knowledge or lack novelty.

Performance Issues

There can be performance-related issues such as follows −

- **Efficiency and scalability of data mining algorithms** − In order to effectively extract the information from huge amount of data in databases, data mining algorithm must be efficient and scalable.
- **Parallel, distributed, and incremental mining algorithms** − The factors such as huge size of databases, wide distribution of data, and complexity of data mining methods motivate the development of parallel and distributed data mining algorithms. These algorithms divide the data into partitions which is further processed in a parallel fashion. Then the results from the partitions is merged. The incremental algorithms, update databases without mining the data again from scratch.

Diverse Data Types Issues

- **Handling of relational and complex types of data** − The database may contain complex data objects, multimedia data objects, spatial data, temporal data etc. It is not possible for one system to mine all these kind of data.
- **Mining information from heterogeneous databases and global information systems** − The data is available at different data sources on LAN or WAN. These data

source may be structured, semi structured or unstructured. Therefore mining the knowledge from them adds challenges to data mining.

Data Mining - Evaluation

Data Warehouse

A data warehouse exhibits the following characteristics to support the management's decision-making process −

- **Subject Oriented** − Data warehouse is subject oriented because it provides us the information around a subject rather than the organization's ongoing operations. These subjects can be product, customers, suppliers, sales, revenue, etc. The data warehouse does not focus on the ongoing operations, rather it focuses on modelling and analysis of data for decision-making.
- **Integrated** − Data warehouse is constructed by integration of data from heterogeneous sources such as relational databases, flat files etc. This integration enhances the effective analysis of data.
- **Time Variant** − The data collected in a data warehouse is identified with a particular time period. The data in a data warehouse provides information from a historical point of view.
- **Non-volatile** − Nonvolatile means the previous data is not removed when new data is added to it. The data warehouse is kept separate from the operational database therefore frequent changes in operational database is not reflected in the data warehouse.

Data Warehousing

Data warehousing is the process of constructing and using the data warehouse. A data warehouse is constructed by integrating the data from multiple heterogeneous sources. It supports analytical reporting, structured and/or ad hoc queries, and decision making.

Data warehousing involves data cleaning, data integration, and data consolidations. To integrate heterogeneous databases, we have the following two approaches −

- Query Driven Approach
- Update Driven Approach

Query-Driven Approach

This is the traditional approach to integrate heterogeneous databases. This approach is used to build wrappers and integrators on top of multiple heterogeneous databases. These integrators are also known as mediators.

Process of Query Driven Approach

- When a query is issued to a client side, a metadata dictionary translates the query into the queries, appropriate for the individual heterogeneous site involved.
- Now these queries are mapped and sent to the local query processor.
- The results from heterogeneous sites are integrated into a global answer set.

Disadvantages

This approach has the following disadvantages −

- The Query Driven Approach needs complex integration and filtering processes.
- It is very inefficient and very expensive for frequent queries.
- This approach is expensive for queries that require aggregations.

Update-Driven Approach

Today's data warehouse systems follow update-driven approach rather than the traditional approach discussed earlier. In the update-driven approach, the information from multiple heterogeneous sources is integrated in advance and stored in a warehouse. This information is available for direct querying and analysis.

Advantages

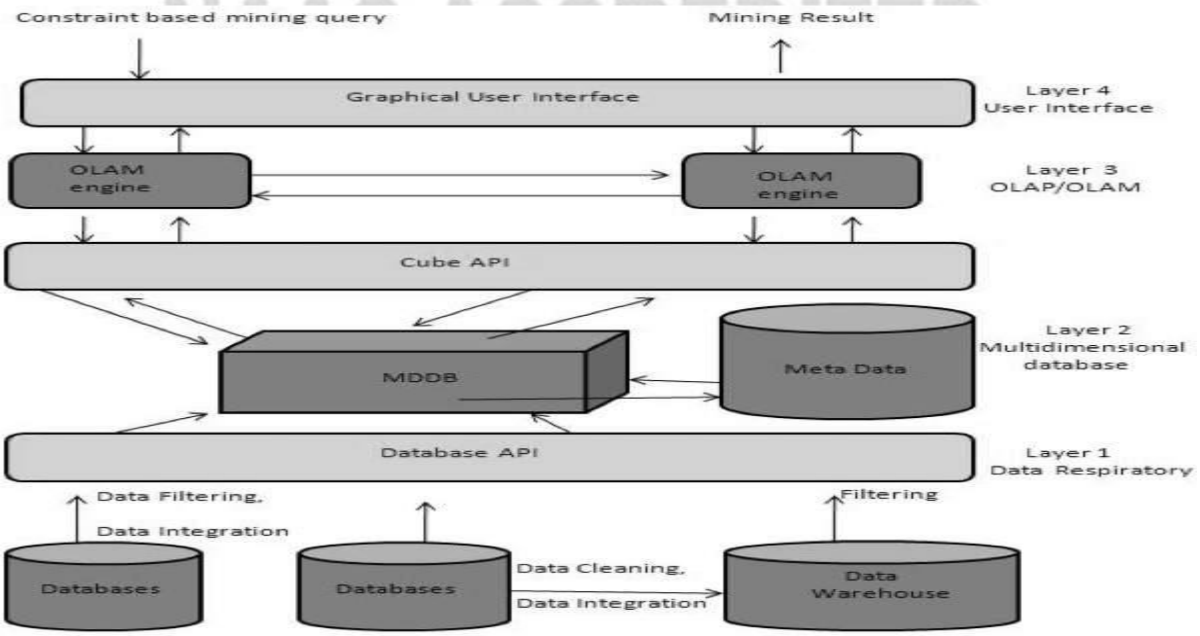
This approach has the following advantages −

- This approach provides high performance.
- The data can be copied, processed, integrated, annotated, summarized and restructured in the semantic data store in advance.

Query processing does not require interface with the processing at local sources.

From Data Warehousing (OLAP) to Data Mining (OLAM)

Online Analytical Mining integrates with Online Analytical Processing with data mining and mining knowledge in multidimensional databases. Here is the diagram that shows the integration of both OLAP and OLAM −



Importance of OLAM

OLAM is important for the following reasons −

- **High quality of data in data warehouses** − The data mining tools are required to work on integrated, consistent, and cleaned data. These steps are very costly in the preprocessing of data. The data warehouses constructed by such preprocessing are valuable sources of high quality data for OLAP and data mining as well.
- **Available information processing infrastructure surrounding data warehouses** − Information processing infrastructure refers to accessing, integration, consolidation, and transformation of multiple heterogeneous databases, web-accessing and service facilities, reporting and OLAP analysis tools.
- **OLAP−based exploratory data analysis** − Exploratory data analysis is required for effective data mining. OLAM provides facility for data mining on various subset of data and at different levels of abstraction.

- **Online selection of data mining functions** − Integrating OLAP with multiple data mining functions and online analytical mining provide users with the flexibility to select desired data mining functions and swap data mining tasks dynamically.

Data Mining - Terminologies

Data Mining

Data mining is defined as extracting the information from a huge set of data. In other words we can say that data mining is mining the knowledge from data. This information can be used for any of the following applications −

- Market Analysis
- Fraud Detection
- Customer Retention
- Production Control
- Science Exploration

Data Mining Engine

Data mining engine is very essential to the data mining system. It consists of a set of functional modules that perform the following functions −

- Characterization
- Association and Correlation Analysis
- Classification
- Prediction
- Cluster analysis
- Outlier analysis
- Evolution analysis

Knowledge Base

This is the domain knowledge. This knowledge is used to guide the search or evaluate the interestingness of the resulting patterns.

Knowledge Discovery

Some people treat data mining same as knowledge discovery, while others view data mining as an essential step in the process of knowledge discovery. Here is the list of steps involved in the knowledge discovery process −

- Data Cleaning
- Data Integration
- Data Selection
- Data Transformation
- Data Mining
- Pattern Evaluation
- Knowledge Presentation

User interface

User interface is the module of data mining system that helps the communication between users and the data mining system. User Interface allows the following functionalities −

- Interact with the system by specifying a data mining query task.
- Providing information to help focus the search.
- Mining based on the intermediate data mining results.
- Browse database and data warehouse schemas or data structures.
- Evaluate mined patterns.
- Visualize the patterns in different forms.

Data Integration

Data Integration is a data preprocessing technique that merges the data from multiple heterogeneous data sources into a coherent data store. Data integration may involve inconsistent data and therefore needs data cleaning.

Data Cleaning

Data cleaning is a technique that is applied to remove the noisy data and correct the inconsistencies in data. Data cleaning involves transformations to correct the wrong data. Data cleaning is performed as a data preprocessing step while preparing the data for a data warehouse.

Data Selection

Data Selection is the process where data relevant to the analysis task are retrieved from the database. Sometimes data transformation and consolidation are performed before the data selection process.

Clusters

Cluster refers to a group of similar kind of objects. Cluster analysis refers to forming group of objects that are very similar to each other but are highly different from the objects in other clusters.

Data Transformation

In this step, data is transformed or consolidated into forms appropriate for mining, by performing summary or aggregation operations.

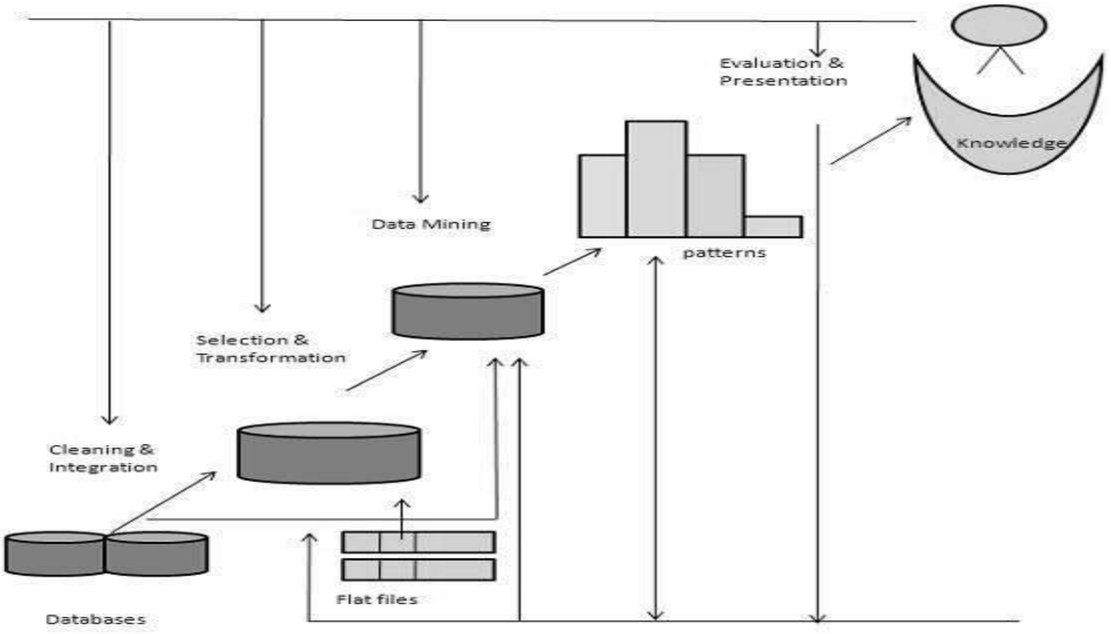
Data Mining - Knowledge Discovery

What is Knowledge Discovery?

Some people don't differentiate data mining from knowledge discovery while others view data mining as an essential step in the process of knowledge discovery. Here is the list of steps involved in the knowledge discovery process −

- **Data Cleaning** − In this step, the noise and inconsistent data is removed.
- **Data Integration** − In this step, multiple data sources are combined.
- **Data Selection** − In this step, data relevant to the analysis task are retrieved from the database.
- **Data Transformation** − In this step, data is transformed or consolidated into forms appropriate for mining by performing summary or aggregation operations.
- **Data Mining** − In this step, intelligent methods are applied in order to extract data patterns.
- **Pattern Evaluation** − In this step, data patterns are evaluated.
- **Knowledge Presentation** − In this step, knowledge is represented.

The following diagram shows the process of knowledge discovery −



Data Mining - Systems

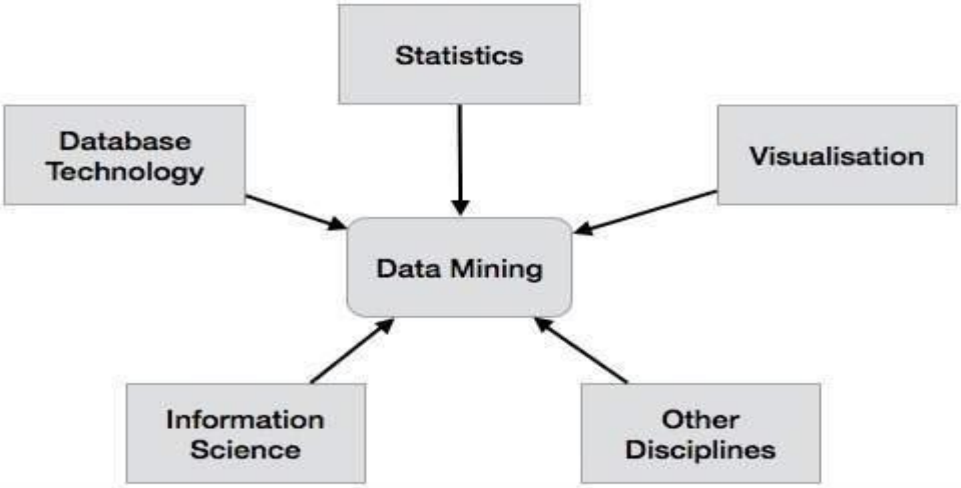
There is a large variety of data mining systems available. Data mining systems may integrate techniques from the following −

- Spatial Data Analysis
- Information Retrieval
- Pattern Recognition
- Image Analysis
- Signal Processing
- Computer Graphics
- Web Technology
- Business
- Bioinformatics

Data Mining System Classification

A data mining system can be classified according to the following criteria −

- Database Technology
- Statistics
- Machine Learning
- Information Science
- Visualization
- Other Disciplines



Apart from these, a data mining system can also be classified based on the kind of (a) databases mined, (b) knowledge mined, (c) techniques utilized, and (d) applications adapted.

Classification Based on the Databases Mined

We can classify a data mining system according to the kind of databases mined. Database system can be classified according to different criteria such as data models, types of data, etc. And the data mining system can be classified accordingly.

For example, if we classify a database according to the data model, then we may have a relational, transactional, object-relational, or data warehouse mining system.

Classification Based on the kind of Knowledge Mined

We can classify a data mining system according to the kind of knowledge mined. It means the data mining system is classified on the basis of functionalities such as −

- Characterization
- Discrimination

- Association and Correlation Analysis
- Classification
- Prediction
- Outlier Analysis
- Evolution Analysis

Classification Based on the Techniques Utilized

We can classify a data mining system according to the kind of techniques used. We can describe these techniques according to the degree of user interaction involved or the methods of analysis employed.

Classification Based on the Applications Adapted

We can classify a data mining system according to the applications adapted. These applications are as follows −

- Finance
- Telecommunications
- DNA
- Stock Markets
- E-mail

Integrating a Data Mining System with a DB/DW System

If a data mining system is not integrated with a database or a data warehouse system, then there will be no system to communicate with. This scheme is known as the non-coupling scheme. In this scheme, the main focus is on data mining design and on developing efficient and effective algorithms for mining the available data sets.

The list of Integration Schemes is as follows −

- **No Coupling** − In this scheme, the data mining system does not utilize any of the database or data warehouse functions. It fetches the data from a particular source and processes that data using some data mining algorithms. The data mining result is stored in another file.

- **Loose Coupling** − In this scheme, the data mining system may use some of the functions of database and data warehouse system. It fetches the data from the data respiratory managed by these systems and performs data mining on that data. It then stores the mining result either in a file or in a designated place in a database or in a data warehouse.
- **Semi−tight Coupling** − In this scheme, the data mining system is linked with a database or a data warehouse system and in addition to that, efficient implementations of a few data mining primitives can be provided in the database.
- **Tight coupling** − In this coupling scheme, the data mining system is smoothly integrated into the database or data warehouse system. The data mining subsystem is treated as one functional component of an information system.

Data Mining - Query Language

The Data Mining Query Language (DMQL) was proposed by Han, Fu, Wang, et al. for the DBMiner data mining system. The Data Mining Query Language is actually based on the Structured Query Language (SQL). Data Mining Query Languages can be designed to support ad hoc and interactive data mining. This DMQL provides commands for specifying primitives. The DMQL can work with databases and data warehouses as well. DMQL can be used to define data mining tasks. Particularly we examine how to define data warehouses and data marts in DMQL.

Syntax for Task-Relevant Data Specification

Here is the syntax of DMQL for specifying task-relevant data −

```
use database database_name

or

use data warehouse data_warehouse_name
in relevance to att_or_dim_list
from relation(s)/cube(s) [where condition]
order by order_list
group by grouping_list
```

Syntax for Specifying the Kind of Knowledge

Here we will discuss the syntax for Characterization, Discrimination, Association, Classification, and Prediction.

Characterization

The syntax for characterization is −

```
mine characteristics [as pattern_name]
   analyze  {measure(s) }
```

The analyze clause, specifies aggregate measures, such as count, sum, or count%.

For example −

```
Description describing customer purchasing habits.
mine characteristics as customerPurchasing
analyze count%
```

Discrimination

The syntax for Discrimination is −

```
mine comparison [as {pattern_name]}
For {target_class } where  {t arget_condition }
{versus  {contrast_class_i }
where {contrast_condition_i}}
analyze  {measure(s) }
```

For example, a user may define big spenders as customers who purchase items that cost $100 or more on an average; and budget spenders as customers who purchase items at less than $100 on an average. The mining of discriminant descriptions for customers from each of these categories can be specified in the DMQL as −

```
mine comparison as purchaseGroups
for bigSpenders where avg(I.price) ≥$100
versus budgetSpenders where avg(I.price)< $100
analyze count
```

Association

The syntax for Association is−

```
mine associations [ as {pattern_name} ]
```

```
{matching {metapattern} }
```

For Example −

```
mine associations as buyingHabits
matching P(X:customer,W) ^ Q(X,Y) ≥ buys(X,Z)
```

where X is key of customer relation; P and Q are predicate variables; and W, Y, and Z are object variables.

Classification

The syntax for Classification is −

```
mine classification [as pattern_name]
analyze classifying_attribute_or_dimension
```

For example, to mine patterns, classifying customer credit rating where the classes are determined by the attribute credit_rating, and mine classification is determined as classifyCustomerCreditRating.

```
analyze credit_rating
```

Prediction

The syntax for prediction is −

```
mine prediction [as pattern_name]
analyze prediction_attribute_or_dimension
{set {attribute_or_dimension_i= value_i}}
```

Syntax for Concept Hierarchy Specification

To specify concept hierarchies, use the following syntax −

```
use hierarchy <hierarchy> for <attribute_or_dimension>
```

We use different syntaxes to define different types of hierarchies such as−

```
-schema hierarchies
define hierarchy time_hierarchy on date as [date,month quarter,year]
-
set-grouping hierarchies
define hierarchy age_hierarchy for age on customer as
level1: {young, middle_aged, senior} < level0: all
level2: {20, ..., 39} < level1: young
```

```
level3: {40, ..., 59} < level1: middle_aged
level4: {60, ..., 89} < level1: senior

-operation-derived hierarchies
define hierarchy age_hierarchy  for age  on customer  as
{age_category(1), ..., age_category(5)}
:= cluster(default, age, 5) < all(age)

-rule-based hierarchies
define hierarchy profit_margin_hierarchy  on item  as
level_1: low_profit_margin < level_0:  all

if (price - cost)< $50
  level_1:  medium-profit_margin < level_0:  all

if ((price - cost) > $50)  and ((price - cost) ≤ $250))
  level_1:  high_profit_margin < level_0:  all
```

Syntax for Interestingness Measures Specification

Interestingness measures and thresholds can be specified by the user with the statement −

```
with <interest_measure_name>  threshold = threshold_value
```

For Example −

```
with support threshold = 0.05
with confidence threshold = 0.7
```

Syntax for Pattern Presentation and Visualization Specification

We have a syntax, which allows users to specify the display of discovered patterns in one or more forms.

```
display as <result_form>
```

For Example −

```
display as table
```

Full Specification of DMQL

As a market manager of a company, you would like to characterize the buying habits of customers who can purchase items priced at no less than $100; with respect to the customer's age, type of item purchased, and the place where the item was purchased. You would like to know the percentage of customers having that characteristic. In particular, you are only interested in purchases made in Canada, and paid with an American Express credit card. You would like to view the resulting descriptions in the form of a table.

```
use database AllElectronics_db
use hierarchy location_hierarchy for B.address
mine characteristics as customerPurchasing
analyze count%
in relevance to C.age,I.type,I.place_made
from customer C, item I, purchase P, items_sold S,  branch B
where I.item_ID = S.item_ID and P.cust_ID = C.cust_ID and
P.method_paid = "AmEx" and B.address = "Canada" and I.price ≥ 100
with noise threshold = 5%
display as table
```

Data Mining Languages Standardization

Standardizing the Data Mining Languages will serve the following purposes −

- Helps systematic development of data mining solutions.
- Improves interoperability among multiple data mining systems and functions.
- Promotes education and rapid learning.
- Promotes the use of data mining systems in industry and society.

Data Mining - Classification & Prediction

There are two forms of data analysis that can be used for extracting models describing important classes or to predict future data trends. These two forms are as follows −

- Classification
- Prediction

Classification models predict categorical class labels; and prediction models predict continuous valued functions. For example, we can build a classification model to categorize bank loan applications as either safe or risky, or a prediction model to predict the expenditures in dollars of potential customers on computer equipment given their income and occupation.

What is classification?

Following are the examples of cases where the data analysis task is Classification −

- A bank loan officer wants to analyze the data in order to know which customer (loan applicant) are risky or which are safe.
- A marketing manager at a company needs to analyze a customer with a given profile, who will buy a new computer.

In both of the above examples, a model or classifier is constructed to predict the categorical labels. These labels are risky or safe for loan application data and yes or no for marketing data.

What is prediction?

Following are the examples of cases where the data analysis task is Prediction −

Suppose the marketing manager needs to predict how much a given customer will spend during a sale at his company. In this example we are bothered to predict a numeric value. Therefore the data analysis task is an example of numeric prediction. In this case, a model or a predictor will be constructed that predicts a continuous-valued-function or ordered value.

Note − Regression analysis is a statistical methodology that is most often used for numeric prediction.

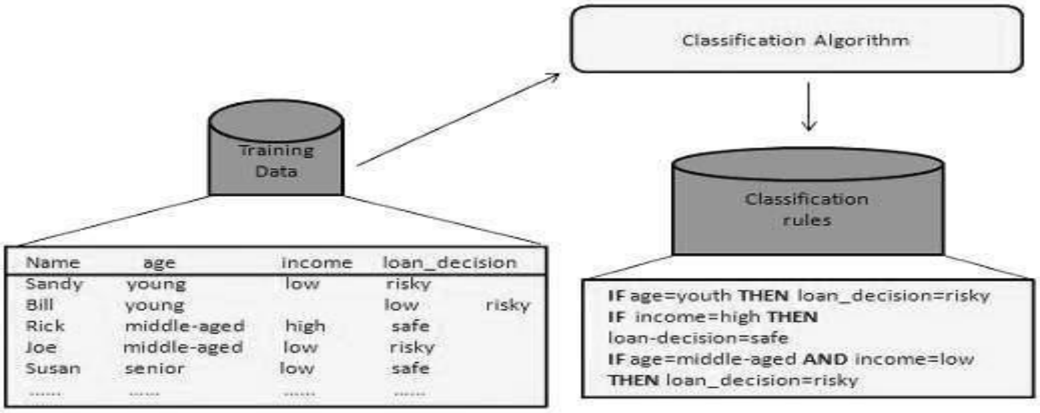
How Does Classification Works?

With the help of the bank loan application that we have discussed above, let us understand the working of classification. The Data Classification process includes two steps −

- Building the Classifier or Model
- Using Classifier for Classification

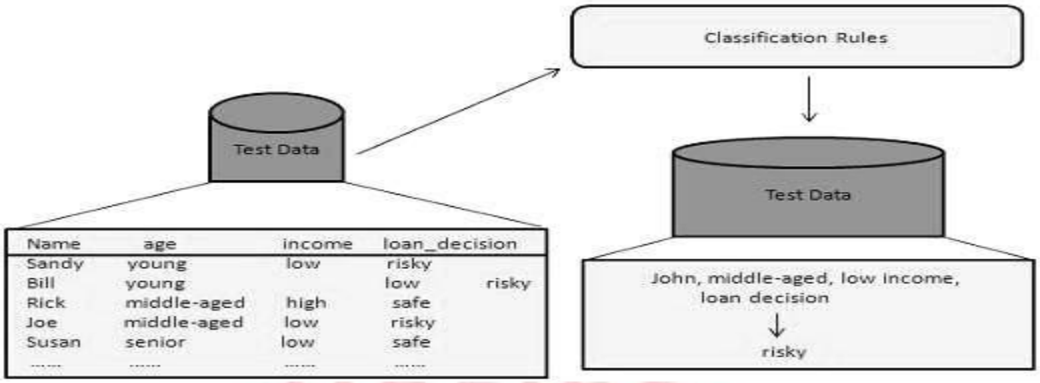
Building the Classifier or Model

- This step is the learning step or the learning phase.
- In this step the classification algorithms build the classifier.
- The classifier is built from the training set made up of database tuples and their associated class labels.
- Each tuple that constitutes the training set is referred to as a category or class. These tuples can also be referred to as sample, object or data points.


Classification Algorithm
Training Data
Classification rules
Name age income loan_decision
Sandy young low risky
Bill young low risky
Rick middle-aged high safe
Joe middle-aged low risky
Susan senior low safe
....
IF age=youth THEN loan_decision=risky
IF income=high THEN loan-decision=safe
IF age=middle-aged AND income=low THEN loan_decision=risky

Using Classifier for Classification

In this step, the classifier is used for classification. Here the test data is used to estimate the accuracy of classification rules. The classification rules can be applied to the new data tuples if the accuracy is considered acceptable.



Classification and Prediction Issues

The major issue is preparing the data for Classification and Prediction. Preparing the data involves the following activities −

- **Data Cleaning** − Data cleaning involves removing the noise and treatment of missing values. The noise is removed by applying smoothing techniques and the problem of missing values is solved by replacing a missing value with most commonly occurring value for that attribute.

- **Relevance Analysis** − Database may also have the irrelevant attributes. Correlation analysis is used to know whether any two given attributes are related.

- **Data Transformation and reduction** − The data can be transformed by any of the following methods.
  - **Normalization** − The data is transformed using normalization. Normalization involves scaling all values for given attribute in order to make them fall within a small specified range. Normalization is used when in the learning step, the neural networks or the methods involving measurements are used.
  - **Generalization** − The data can also be transformed by generalizing it to the higher concept. For this purpose we can use the concept hierarchies.

Note − Data can also be reduced by some other methods such as wavelet transformation, binning, histogram analysis, and clustering.

Comparison of Classification and Prediction Methods

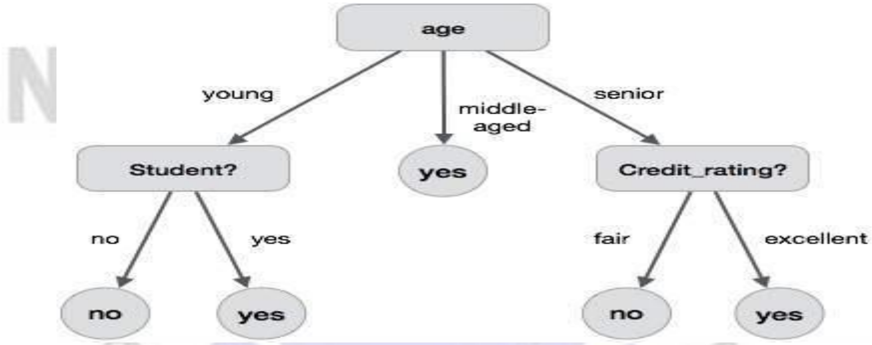
Here is the criteria for comparing the methods of Classification and Prediction −

- **Accuracy** − Accuracy of classifier refers to the ability of classifier. It predict the class label correctly and the accuracy of the predictor refers to how well a given predictor can guess the value of predicted attribute for a new data.
- **Speed** − This refers to the computational cost in generating and using the classifier or predictor.
- **Robustness** − It refers to the ability of classifier or predictor to make correct predictions from given noisy data.
- **Scalability** − Scalability refers to the ability to construct the classifier or predictor efficiently; given large amount of data.
- **Interpretability** − It refers to what extent the classifier or predictor understands.

Data Mining - Decision Tree Induction

A decision tree is a structure that includes a root node, branches, and leaf nodes. Each internal node denotes a test on an attribute, each branch denotes the outcome of a test, and each leaf node holds a class label. The topmost node in the tree is the root node.

The following decision tree is for the concept buy_computer that indicates whether a customer at a company is likely to buy a computer or not. Each internal node represents a test on an attribute. Each leaf node represents a class.



The benefits of having a decision tree are as follows −

- It does not require any domain knowledge.
- It is easy to comprehend.
- The learning and classification steps of a decision tree are simple and fast.

Decision Tree Induction Algorithm

A machine researcher named J. Ross Quinlan in 1980 developed a decision tree algorithm known as ID3 (Iterative Dichotomiser). Later, he presented C4.5, which was the successor of ID3. ID3 and C4.5 adopt a greedy approach. In this algorithm, there is no backtracking; the trees are constructed in a top-down recursive divide-and-conquer manner.

Generating a decision tree form training tuples of data partition D
Algorithm : Generate_decision_tree

Input:
Data partition, D, which is a set of training tuples
and their associated class labels.
attribute_list, the set of candidate attributes.
Attribute selection method, a procedure to determine the
splitting criterion that best partitions that the data
tuples into individual classes. This criterion includes a
splitting_attribute and either a splitting point or splitting subset.

Output:
A Decision Tree

Method

```
create a node N;

if tuples in D are all of the same class, C then
   return N as leaf node labeled with class C;

if attribute_list is empty then
   return N as leaf node with labeled
   with majority class in D;|| majority voting

apply attribute_selection_method(D, attribute_list)
to find the best splitting_criterion;
label node N with splitting_criterion;

if splitting_attribute is discrete-valued and
   multiway splits allowed then  // no restricted to binary trees

attribute_list = splitting attribute; // remove splitting attribute
for each outcome j of splitting criterion

   // partition the tuples and grow subtrees for each partition
   let Dj be the set of data tuples in D satisfying outcome j; // a partition

   if Dj is empty then
      attach a leaf labeled with the majority
      class in D to node N;
   else
      attach the node returned by Generate
      decision tree(Dj, attribute list) to node N;
   end for
return N;
```

Tree Pruning

Tree pruning is performed in order to remove anomalies in the training data due to noise or outliers. The pruned trees are smaller and less complex.

Tree Pruning Approaches

There are two approaches to prune a tree −

- **Pre-pruning** − The tree is pruned by halting its construction early.

- **Post-pruning** - This approach removes a sub-tree from a fully grown tree.

Cost Complexity

The cost complexity is measured by the following two parameters −

- Number of leaves in the tree, and
- Error rate of the tree.

Data Mining - Bayesian Classification

Bayesian classification is based on Bayes' Theorem. Bayesian classifiers are the statistical classifiers. Bayesian classifiers can predict class membership probabilities such as the probability that a given tuple belongs to a particular class.

Baye's Theorem

Bayes' Theorem is named after Thomas Bayes. There are two types of probabilities −

- Posterior Probability [P(H/X)]
- Prior Probability [P(H)]

where X is data tuple and H is some hypothesis.

According to Bayes' Theorem,

$$P(H/X)= P(X/H)P(H) / P(X)$$

Bayesian Belief Network

Bayesian Belief Networks specify joint conditional probability distributions. They are also known as Belief Networks, Bayesian Networks, or Probabilistic Networks.

- A Belief Network allows class conditional independencies to be defined between subsets of variables.
- It provides a graphical model of causal relationship on which learning can be performed.
- We can use a trained Bayesian Network for classification.

There are two components that define a Bayesian Belief Network −

- Directed acyclic graph

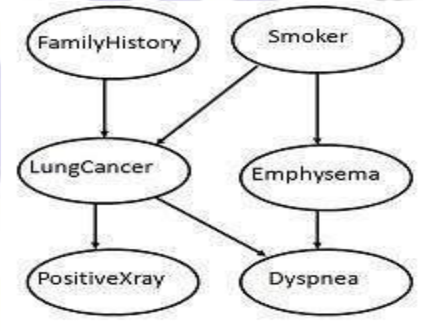
- A set of conditional probability tables

Directed Acyclic Graph

- Each node in a directed acyclic graph represents a random variable.
- These variable may be discrete or continuous valued.
- These variables may correspond to the actual attribute given in the data.

Directed Acyclic Graph Representation

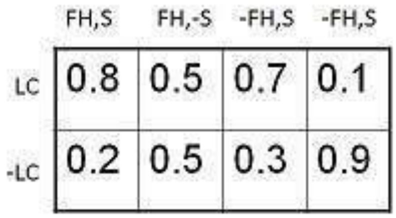
The following diagram shows a directed acyclic graph for six Boolean variables.



The arc in the diagram allows representation of causal knowledge. For example, lung cancer is influenced by a person's family history of lung cancer, as well as whether or not the person is a smoker. It is worth noting that the variable PositiveXray is independent of whether the patient has a family history of lung cancer or that the patient is a smoker, given that we know the patient has lung cancer.

Conditional Probability Table

The conditional probability table for the values of the variable LungCancer (LC) showing each possible combination of the values of its parent nodes, FamilyHistory (FH), and Smoker (S) is as follows −



	FH,S	FH,-S	-FH,S	-FH,S
LC	0.8	0.5	0.7	0.1
-LC	0.2	0.5	0.3	0.9

Data Mining - Rule Based Classification

IF-THEN Rules

Rule-based classifier makes use of a set of IF-THEN rules for classification. We can express a rule in the following from −

IF condition THEN conclusion

Let us consider a rule R1,

```
R1: IF age = youth AND student = yes
  THEN buy_computer = yes
```

Points to remember −

- The IF part of the rule is called **rule antecedent** or **precondition**.
- The THEN part of the rule is called **rule consequent**.
- The antecedent part the condition consist of one or more attribute tests and these tests are logically ANDed.
- The consequent part consists of class prediction.

Note − We can also write rule R1 as follows −

```
R1: (age = youth) ^ (student = yes))(buys computer = yes)
```

If the condition holds true for a given tuple, then the antecedent is satisfied.

Rule Extraction

Here we will learn how to build a rule-based classifier by extracting IF-THEN rules from a decision tree.

Points to remember −

To extract a rule from a decision tree −

- One rule is created for each path from the root to the leaf node.
- To form a rule antecedent, each splitting criterion is logically ANDed.
- The leaf node holds the class prediction, forming the rule consequent.

Rule Induction Using Sequential Covering Algorithm

Sequential Covering Algorithm can be used to extract IF-THEN rules form the training data. We do not require to generate a decision tree first. In this algorithm, each rule for a given class covers many of the tuples of that class.

Some of the sequential Covering Algorithms are AQ, CN2, and RIPPER. As per the general strategy the rules are learned one at a time. For each time rules are learned, a tuple covered by the rule is removed and the process continues for the rest of the tuples. This is because the path to each leaf in a decision tree corresponds to a rule.

Note − The Decision tree induction can be considered as learning a set of rules simultaneously.

The Following is the sequential learning Algorithm where rules are learned for one class at a time. When learning a rule from a class Ci, we want the rule to cover all the tuples from class C only and no tuple form any other class.

```
Algorithm: Sequential Covering

Input:
D, a data set class-labeled tuples,
Att_vals, the set of all attributes and their possible values.

Output:  A Set of IF-THEN rules.
Method:
Rule_set={ }; // initial set of rules learned is empty

for each class c do

  repeat
    Rule = Learn_One_Rule(D, Att_valls, c);
    remove tuples covered by Rule form D;
  until termination condition;

  Rule_set=Rule_set+Rule; // add a new rule to rule-set
end for
return Rule_Set;
```

Rule Pruning

The rule is pruned is due to the following reason −

- The Assessment of quality is made on the original set of training data. The rule may perform well on training data but less well on subsequent data. That's why the rule pruning is required.
- The rule is pruned by removing conjunct. The rule R is pruned, if pruned version of R has greater quality than what was assessed on an independent set of tuples.

FOIL is one of the simple and effective method for rule pruning. For a given rule R,

FOIL_Prune = pos - neg / pos + neg

where pos and neg is the number of positive tuples covered by R, respectively.

Note − This value will increase with the accuracy of R on the pruning set. Hence, if the FOIL_Prune value is higher for the pruned version of R, then we prune R.

Miscellaneous Classification Methods

Here we will discuss other classification methods such as Genetic Algorithms, Rough Set Approach, and Fuzzy Set Approach.

Genetic Algorithms

The idea of genetic algorithm is derived from natural evolution. In genetic algorithm, first of all, the initial population is created. This initial population consists of randomly generated rules. We can represent each rule by a string of bits.

For example, in a given training set, the samples are described by two Boolean attributes such as A1 and A2. And this given training set contains two classes such as C1 and C2.

We can encode the rule **IF A1 AND NOT A2 THEN C2** into a bit string **100**. In this bit representation, the two leftmost bits represent the attribute A1 and A2, respectively.

Likewise, the rule **IF NOT A1 AND NOT A2 THEN C1** can be encoded as **001**.

Note − If the attribute has K values where K>2, then we can use the K bits to encode the attribute values. The classes are also encoded in the same manner.

Points to remember −

- Based on the notion of the survival of the fittest, a new population is formed that consists of the fittest rules in the current population and offspring values of these rules as well.

- The fitness of a rule is assessed by its classification accuracy on a set of training samples.
- The genetic operators such as crossover and mutation are applied to create offspring.
- In crossover, the substring from pair of rules are swapped to form a new pair of rules.
- In mutation, randomly selected bits in a rule's string are inverted.

Rough Set Approach

We can use the rough set approach to discover structural relationship within imprecise and noisy data.

Note − This approach can only be applied on discrete-valued attributes. Therefore, continuous-valued attributes must be discretized before its use.

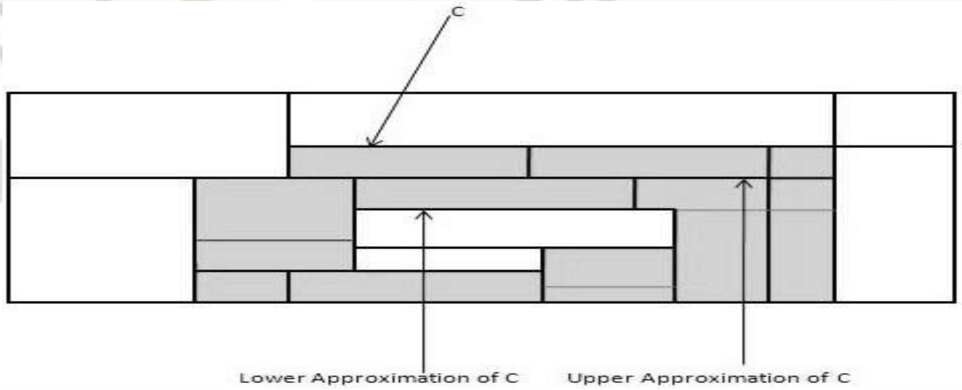
The Rough Set Theory is based on the establishment of equivalence classes within the given training data. The tuples that forms the equivalence class are indiscernible. It means the samples are identical with respect to the attributes describing the data.

There are some classes in the given real world data, which cannot be distinguished in terms of available attributes. We can use the rough sets to **roughly** define such classes.

For a given class C, the rough set definition is approximated by two sets as follows −

- **Lower Approximation of C** − The lower approximation of C consists of all the data tuples, that based on the knowledge of the attribute, are certain to belong to class C.
- **Upper Approximation of C** − The upper approximation of C consists of all the tuples, that based on the knowledge of attributes, cannot be described as not belonging to C.

The following diagram shows the Upper and Lower Approximation of class C −



Fuzzy Set Approaches

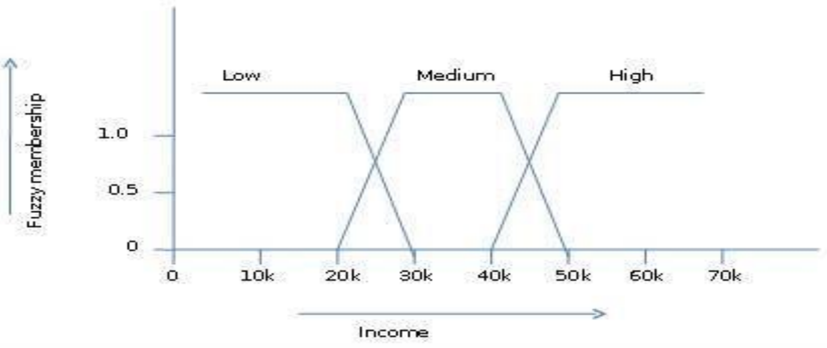
Fuzzy Set Theory is also called Possibility Theory. This theory was proposed by Lotfi Zadeh in 1965 as an alternative the **two-value logic** and **probability theory**. This theory allows us to work at a high level of abstraction. It also provides us the means for dealing with imprecise measurement of data.

The fuzzy set theory also allows us to deal with vague or inexact facts. For example, being a member of a set of high incomes is in exact (e.g. if $50,000 is high then what about $49,000 and $48,000). Unlike the traditional CRISP set where the element either belong to S or its complement but in fuzzy set theory the element can belong to more than one fuzzy set.

For example, the income value $49,000 belongs to both the medium and high fuzzy sets but to differing degrees. Fuzzy set notation for this income value is as follows −

$m_{medium\_income}(\$49k)=0.15$ and $m_{high\_income}(\$49k)=0.96$

where 'm' is the membership function that operates on the fuzzy sets of medium_income and high_income respectively. This notation can be shown diagrammatically as follows −



Data Mining - Cluster Analysis

Cluster is a group of objects that belongs to the same class. In other words, similar objects are grouped in one cluster and dissimilar objects are grouped in another cluster.

What is Clustering?

Clustering is the process of making a group of abstract objects into classes of similar objects.

Points to Remember

- A cluster of data objects can be treated as one group.

- While doing cluster analysis, we first partition the set of data into groups based on data similarity and then assign the labels to the groups.
- The main advantage of clustering over classification is that, it is adaptable to changes and helps single out useful features that distinguish different groups.

Applications of Cluster Analysis

- Clustering analysis is broadly used in many applications such as market research, pattern recognition, data analysis, and image processing.
- Clustering can also help marketers discover distinct groups in their customer base. And they can characterize their customer groups based on the purchasing patterns.
- In the field of biology, it can be used to derive plant and animal taxonomies, categorize genes with similar functionalities and gain insight into structures inherent to populations.
- Clustering also helps in identification of areas of similar land use in an earth observation database. It also helps in the identification of groups of houses in a city according to house type, value, and geographic location.
- Clustering also helps in classifying documents on the web for information discovery.
- Clustering is also used in outlier detection applications such as detection of credit card fraud.
- As a data mining function, cluster analysis serves as a tool to gain insight into the distribution of data to observe characteristics of each cluster.

Requirements of Clustering in Data Mining

The following points throw light on why clustering is required in data mining −

- **Scalability** − We need highly scalable clustering algorithms to deal with large databases.
- **Ability to deal with different kinds of attributes** − Algorithms should be capable to be applied on any kind of data such as interval-based (numerical) data, categorical, and binary data.

- **Discovery of clusters with attribute shape** − The clustering algorithm should be capable of detecting clusters of arbitrary shape. They should not be bounded to only distance measures that tend to find spherical cluster of small sizes.
- **High dimensionality** − The clustering algorithm should not only be able to handle low-dimensional data but also the high dimensional space.
- **Ability to deal with noisy data** − Databases contain noisy, missing or erroneous data. Some algorithms are sensitive to such data and may lead to poor quality clusters.
- **Interpretability** − The clustering results should be interpretable, comprehensible, and usable.

Clustering Methods

Clustering methods can be classified into the following categories −

- Partitioning Method
- Hierarchical Method
- Density-based Method
- Grid-Based Method
- Model-Based Method
- Constraint-based Method

Partitioning Method

Suppose we are given a database of 'n' objects and the partitioning method constructs 'k' partition of data. Each partition will represent a cluster and k ≤ n. It means that it will classify the data into k groups, which satisfy the following requirements −

- Each group contains at least one object.
- Each object must belong to exactly one group.

Points to remember −

- For a given number of partitions (say k), the partitioning method will create an initial partitioning.

- Then it uses the iterative relocation technique to improve the partitioning by moving objects from one group to other.

Hierarchical Methods

This method creates a hierarchical decomposition of the given set of data objects. We can classify hierarchical methods on the basis of how the hierarchical decomposition is formed. There are two approaches here −

- Agglomerative Approach
- Divisive Approach

Agglomerative Approach

This approach is also known as the bottom-up approach. In this, we start with each object forming a separate group. It keeps on merging the objects or groups that are close to one another. It keep on doing so until all of the groups are merged into one or until the termination condition holds.

Divisive Approach

This approach is also known as the top-down approach. In this, we start with all of the objects in the same cluster. In the continuous iteration, a cluster is split up into smaller clusters. It is down until each object in one cluster or the termination condition holds. This method is rigid, i.e., once a merging or splitting is done, it can never be undone.

Approaches to Improve Quality of Hierarchical Clustering

Here are the two approaches that are used to improve the quality of hierarchical clustering −

- Perform careful analysis of object linkages at each hierarchical partitioning.
- Integrate hierarchical agglomeration by first using a hierarchical agglomerative algorithm to group objects into micro-clusters, and then performing macro-clustering on the micro-clusters.

Density-based Method

This method is based on the notion of density. The basic idea is to continue growing the given cluster as long as the density in the neighborhood exceeds some threshold, i.e., for each data point within a given cluster, the radius of a given cluster has to contain at least a minimum number of points.

Grid-based Method

In this, the objects together form a grid. The object space is quantized into finite number of cells that form a grid structure.

Advantage

- The major advantage of this method is fast processing time.
- It is dependent only on the number of cells in each dimension in the quantized space.

Model-based methods

In this method, a model is hypothesized for each cluster to find the best fit of data for a given model. This method locates the clusters by clustering the density function. It reflects spatial distribution of the data points.

This method also provides a way to automatically determine the number of clusters based on standard statistics, taking outlier or noise into account. It therefore yields robust clustering methods.

Constraint-based Method

In this method, the clustering is performed by the incorporation of user or application-oriented constraints. A constraint refers to the user expectation or the properties of desired clustering results. Constraints provide us with an interactive way of communication with the clustering process. Constraints can be specified by the user or the application requirement.

Data Mining - Mining Text Data

Text databases consist of huge collection of documents. They collect these information from several sources such as news articles, books, digital libraries, e-mail messages, web pages, etc. Due to increase in the amount of information, the text databases are growing rapidly. In many of the text databases, the data is semi-structured.

For example, a document may contain a few structured fields, such as title, author, publishing_date, etc. But along with the structure data, the document also contains unstructured text components, such as abstract and contents. Without knowing what could be in the documents, it is difficult to formulate effective queries for analyzing and extracting useful information from the data. Users require tools to compare the documents and rank their importance and relevance. Therefore, text mining has become popular and an essential theme in data mining.

Information Retrieval

Information retrieval deals with the retrieval of information from a large number of text-based documents. Some of the database systems are not usually present in information retrieval systems because both handle different kinds of data. Examples of information retrieval system include −

- Online Library catalogue system
- Online Document Management Systems
- Web Search Systems etc.

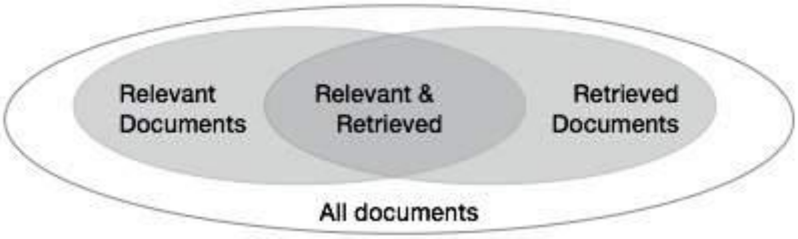
Note − The main problem in an information retrieval system is to locate relevant documents in a document collection based on a user's query. This kind of user's query consists of some keywords describing an information need.

In such search problems, the user takes an initiative to pull relevant information out from a collection. This is appropriate when the user has ad-hoc information need, i.e., a short-term need. But if the user has a long-term information need, then the retrieval system can also take an initiative to push any newly arrived information item to the user.

This kind of access to information is called Information Filtering. And the corresponding systems are known as Filtering Systems or Recommender Systems.

Basic Measures for Text Retrieval

We need to check the accuracy of a system when it retrieves a number of documents on the basis of user's input. Let the set of documents relevant to a query be denoted as {Relevant} and the set of retrieved document as {Retrieved}. The set of documents that are relevant and retrieved can be denoted as {Relevant} ∩ {Retrieved}. This can be shown in the form of a Venn diagram as follows −



There are three fundamental measures for assessing the quality of text retrieval −

- Precision
- Recall
- F-score

Precision

Precision is the percentage of retrieved documents that are in fact relevant to the query. Precision can be defined as −

Precision= |{Relevant} ∩ {Retrieved}| / |{Retrieved}|

Recall

Recall is the percentage of documents that are relevant to the query and were in fact retrieved. Recall is defined as −

Recall = |{Relevant} ∩ {Retrieved}| / |{Relevant}|

F-score

F-score is the commonly used trade-off. The information retrieval system often needs to trade-off for precision or vice versa. F-score is defined as harmonic mean of recall or precision as follows −

F-score = recall x precision / (recall + precision) / 2

Data Mining - Mining World Wide Web

The World Wide Web contains huge amounts of information that provides a rich source for data mining.

Challenges in Web Mining

The web poses great challenges for resource and knowledge discovery based on the following observations −

- **The web is too huge** − The size of the web is very huge and rapidly increasing. This seems that the web is too huge for data warehousing and data mining.
- **Complexity of Web pages** − The web pages do not have unifying structure. They are very complex as compared to traditional text document. There are huge amount of documents in digital library of web. These libraries are not arranged according to any particular sorted order.
- **Web is dynamic information source** − The information on the web is rapidly updated. The data such as news, stock markets, weather, sports, shopping, etc., are regularly updated.
- **Diversity of user communities** − The user community on the web is rapidly expanding. These users have different backgrounds, interests, and usage purposes. There are more than 100 million workstations that are connected to the Internet and still rapidly increasing.
- **Relevancy of Information** − It is considered that a particular person is generally interested in only small portion of the web, while the rest of the portion of the web contains the information that is not relevant to the user and may swamp desired results.

Mining Web page layout structure

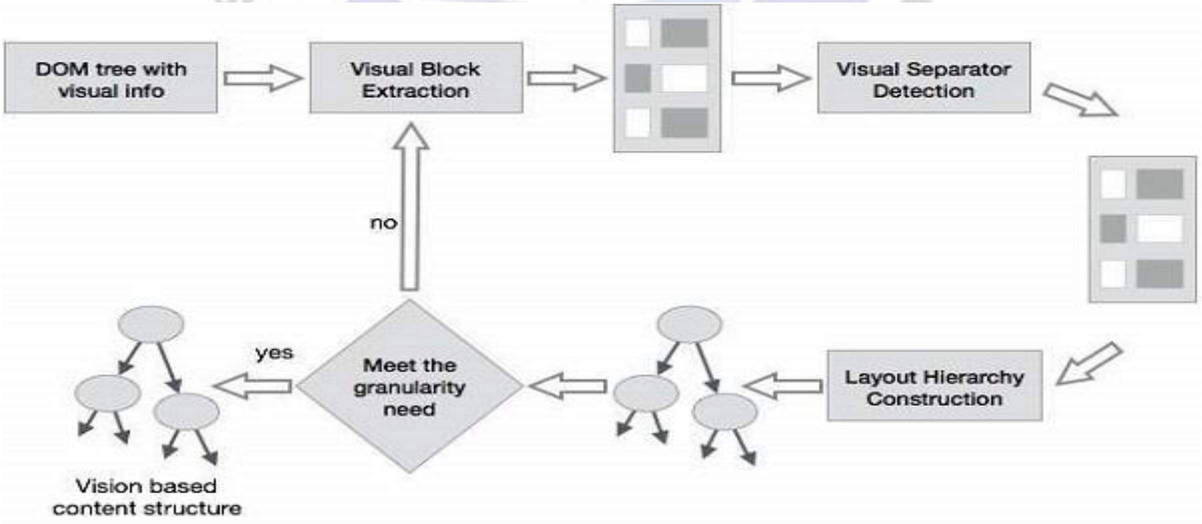
The basic structure of the web page is based on the Document Object Model (DOM). The DOM structure refers to a tree like structure where the HTML tag in the page corresponds to a node in the DOM tree. We can segment the web page by using predefined tags in HTML. The HTML syntax is flexible therefore, the web pages does not follow the W3C specifications. Not following the specifications of W3C may cause error in DOM tree structure.

The DOM structure was initially introduced for presentation in the browser and not for description of semantic structure of the web page. The DOM structure cannot correctly identify the semantic relationship between the different parts of a web page.

Vision-based page segmentation (VIPS)

- The purpose of VIPS is to extract the semantic structure of a web page based on its visual presentation.
- Such a semantic structure corresponds to a tree structure. In this tree each node corresponds to a block.
- A value is assigned to each node. This value is called the Degree of Coherence. This value is assigned to indicate the coherent content in the block based on visual perception.
- The VIPS algorithm first extracts all the suitable blocks from the HTML DOM tree. After that it finds the separators between these blocks.
- The separators refer to the horizontal or vertical lines in a web page that visually cross with no blocks.
- The semantics of the web page is constructed on the basis of these blocks.

The following figure shows the procedure of VIPS algorithm −


DOM tree with visual info
Visual Block Extraction
Visual Separator Detection
no
yes
Meet the granularity need
Layout Hierarchy Construction
Vision based content structure

Data Mining - Applications & Trends

Data mining is widely used in diverse areas. There are a number of commercial data mining system available today and yet there are many challenges in this field. In this tutorial, we will discuss the applications and the trend of data mining.

Data Mining Applications

Here is the list of areas where data mining is widely used −

- Financial Data Analysis
- Retail Industry
- Telecommunication Industry
- Biological Data Analysis
- Other Scientific Applications
- Intrusion Detection

Financial Data Analysis

The financial data in banking and financial industry is generally reliable and of high quality which facilitates systematic data analysis and data mining. Some of the typical cases are as follows −

- Design and construction of data warehouses for multidimensional data analysis and data mining.
- Loan payment prediction and customer credit policy analysis.
- Classification and clustering of customers for targeted marketing.
- Detection of money laundering and other financial crimes.

Retail Industry

Data Mining has its great application in Retail Industry because it collects large amount of data from on sales, customer purchasing history, goods transportation, consumption and services. It is natural that the quantity of data collected will continue to expand rapidly because of the increasing ease, availability and popularity of the web.

Data mining in retail industry helps in identifying customer buying patterns and trends that lead to improved quality of customer service and good customer retention and satisfaction. Here is the list of examples of data mining in the retail industry −

- Design and Construction of data warehouses based on the benefits of data mining.
- Multidimensional analysis of sales, customers, products, time and region.

- Analysis of effectiveness of sales campaigns.
- Customer Retention.
- Product recommendation and cross-referencing of items.

Telecommunication Industry

Today the telecommunication industry is one of the most emerging industries providing various services such as fax, pager, cellular phone, internet messenger, images, e-mail, web data transmission, etc. Due to the development of new computer and communication technologies, the telecommunication industry is rapidly expanding. This is the reason why data mining is become very important to help and understand the business.

Data mining in telecommunication industry helps in identifying the telecommunication patterns, catch fraudulent activities, make better use of resource, and improve quality of service. Here is the list of examples for which data mining improves telecommunication services −

- Multidimensional Analysis of Telecommunication data.
- Fraudulent pattern analysis.
- Identification of unusual patterns.
- Multidimensional association and sequential patterns analysis.
- Mobile Telecommunication services.
- Use of visualization tools in telecommunication data analysis.

Biological Data Analysis

In recent times, we have seen a tremendous growth in the field of biology such as genomics, proteomics, functional Genomics and biomedical research. Biological data mining is a very important part of Bioinformatics. Following are the aspects in which data mining contributes for biological data analysis −

- Semantic integration of heterogeneous, distributed genomic and proteomic databases.
- Alignment, indexing, similarity search and comparative analysis multiple nucleotide sequences.
- Discovery of structural patterns and analysis of genetic networks and protein pathways.

- Association and path analysis.
- Visualization tools in genetic data analysis.

Other Scientific Applications

The applications discussed above tend to handle relatively small and homogeneous data sets for which the statistical techniques are appropriate. Huge amount of data have been collected from scientific domains such as geosciences, astronomy, etc. A large amount of data sets is being generated because of the fast numerical simulations in various fields such as climate and ecosystem modeling, chemical engineering, fluid dynamics, etc. Following are the applications of data mining in the field of Scientific Applications −

- Data Warehouses and data preprocessing.
- Graph-based mining.
- Visualization and domain specific knowledge.

Intrusion Detection

Intrusion refers to any kind of action that threatens integrity, confidentiality, or the availability of network resources. In this world of connectivity, security has become the major issue. With increased usage of internet and availability of the tools and tricks for intruding and attacking network prompted intrusion detection to become a critical component of network administration. Here is the list of areas in which data mining technology may be applied for intrusion detection −

- Development of data mining algorithm for intrusion detection.
- Association and correlation analysis, aggregation to help select and build discriminating attributes.
- Analysis of Stream data.
- Distributed data mining.
- Visualization and query tools.

Data Mining System Products

There are many data mining system products and domain specific data mining applications. The new data mining systems and applications are being added to the previous systems. Also, efforts are being made to standardize data mining languages.

Choosing a Data Mining System

The selection of a data mining system depends on the following features −

- **Data Types** − The data mining system may handle formatted text, record-based data, and relational data. The data could also be in ASCII text, relational database data or data warehouse data. Therefore, we should check what exact format the data mining system can handle.
- **System Issues** − We must consider the compatibility of a data mining system with different operating systems. One data mining system may run on only one operating system or on several. There are also data mining systems that provide web-based user interfaces and allow XML data as input.
- **Data Sources** − Data sources refer to the data formats in which data mining system will operate. Some data mining system may work only on ASCII text files while others on multiple relational sources. Data mining system should also support ODBC connections or OLE DB for ODBC connections.
- **Data Mining functions and methodologies** − There are some data mining systems that provide only one data mining function such as classification while some provides multiple data mining functions such as concept description, discovery-driven OLAP analysis, association mining, linkage analysis, statistical analysis, classification, prediction, clustering, outlier analysis, similarity search, etc.
- **Coupling data mining with databases or data warehouse systems** − Data mining systems need to be coupled with a database or a data warehouse system. The coupled components are integrated into a uniform information processing environment. Here are the types of coupling listed below −
    - No coupling
    - Loose Coupling

  - Semi tight Coupling
  - Tight Coupling

- **Scalability** − There are two scalability issues in data mining −
  - **Row (Database size) Scalability** − A data mining system is considered as row scalable when the number or rows are enlarged 10 times. It takes no more than 10 times to execute a query.
  - **Column (Dimension) Salability** − A data mining system is considered as column scalable if the mining query execution time increases linearly with the number of columns.
- **Visualization Tools** − Visualization in data mining can be categorized as follows −
  - Data Visualization
  - Mining Results Visualization
  - Mining process visualization
  - Visual data mining
- **Data Mining query language and graphical user interface** − An easy-to-use graphical user interface is important to promote user-guided, interactive data mining. Unlike relational database systems, data mining systems do not share underlying data mining query language.

Trends in Data Mining

Data mining concepts are still evolving and here are the latest trends that we get to see in this field −

- Application Exploration.
- Scalable and interactive data mining methods.
- Integration of data mining with database systems, data warehouse systems and web database systems.
- SStandardization of data mining query language.
- Visual data mining.
- New methods for mining complex types of data.

- Biological data mining.
- Data mining and software engineering.
- Web mining.
- Distributed data mining.
- Real time data mining.
- Multi database data mining.
- Privacy protection and information security in data mining.

Data Mining - Themes

Theoretical Foundations of Data Mining

The theoretical foundations of data mining includes the following concepts −

- **Data Reduction** − The basic idea of this theory is to reduce the data representation which trades accuracy for speed in response to the need to obtain quick approximate answers to queries on very large databases. Some of the data reduction techniques are as follows −
  - Singular value Decomposition
  - Wavelets
  - Regression
  - Log-linear models
  - Histograms
  - Clustering
  - Sampling
  - Construction of Index Trees
- **Data Compression** − The basic idea of this theory is to compress the given data by encoding in terms of the following −
  - Bits
  - Association Rules

  - Decision Trees
  - Clusters

- **Pattern Discovery** − The basic idea of this theory is to discover patterns occurring in a database. Following are the areas that contribute to this theory −
  - Machine Learning
  - Neural Network
  - Association Mining
  - Sequential Pattern Matching
  - Clustering
- **Probability Theory** − This theory is based on statistical theory. The basic idea behind this theory is to discover joint probability distributions of random variables.
- **Probability Theory** − According to this theory, data mining finds the patterns that are interesting only to the extent that they can be used in the decision-making process of some enterprise.
- **Microeconomic View** − As per this theory, a database schema consists of data and patterns that are stored in a database. Therefore, data mining is the task of performing induction on databases.
- **Inductive databases** − Apart from the database-oriented techniques, there are statistical techniques available for data analysis. These techniques can be applied to scientific data and data from economic and social sciences as well.

Statistical Data Mining

Some of the Statistical Data Mining Techniques are as follows −

- **Regression** − Regression methods are used to predict the value of the response variable from one or more predictor variables where the variables are numeric. Listed below are the forms of Regression −
  - Linear
  - Multiple

- Weighted
- Polynomial
- Nonparametric
- Robust

- **Generalized Linear Models** − Generalized Linear Model includes −
  - Logistic Regression
  - Poisson Regression

  The model's generalization allows a categorical response variable to be related to a set of predictor variables in a manner similar to the modelling of numeric response variable using linear regression.

- **Analysis of Variance** − This technique analyzes −
  - Experimental data for two or more populations described by a numeric response variable.
  - One or more categorical variables (factors).
- **Mixed-effect Models** − These models are used for analyzing grouped data. These models describe the relationship between a response variable and some co-variates in the data grouped according to one or more factors.
- **Factor Analysis** − Factor analysis is used to predict a categorical response variable. This method assumes that independent variables follow a multivariate normal distribution.
- **Time Series Analysis** − Following are the methods for analyzing time-series data −
  - Auto-regression Methods.
  - Univariate ARIMA (AutoRegressive Integrated Moving Average) Modeling.
  - Long-memory time-series modeling.

Visual Data Mining

Visual Data Mining uses data and/or knowledge visualization techniques to discover implicit knowledge from large data sets. Visual data mining can be viewed as an integration of the following disciplines −

- Data Visualization
- Data Mining

Visual data mining is closely related to the following −

- Computer Graphics
- Multimedia Systems
- Human Computer Interaction
- Pattern Recognition
- High-performance Computing

Generally data visualization and data mining can be integrated in the following ways −

- **Data Visualization** − The data in a database or a data warehouse can be viewed in several visual forms that are listed below −
    - Boxplots
    - 3-D Cubes
    - Data distribution charts
    - Curves
    - Surfaces
    - Link graphs etc.
- **Data Mining Result Visualization** − Data Mining Result Visualization is the presentation of the results of data mining in visual forms. These visual forms could be scattered plots, boxplots, etc.
- **Data Mining Process Visualization** − Data Mining Process Visualization presents the several processes of data mining. It allows the users to see how the data is extracted. It

also allows the users to see from which database or data warehouse the data is cleaned, integrated, preprocessed, and mined.

Audio Data Mining

Audio data mining makes use of audio signals to indicate the patterns of data or the features of data mining results. By transforming patterns into sound and musing, we can listen to pitches and tunes, instead of watching pictures, in order to identify anything interesting.

Data Mining and Collaborative Filtering

Consumers today come across a variety of goods and services while shopping. During live customer transactions, a Recommender System helps the consumer by making product recommendations. The Collaborative Filtering Approach is generally used for recommending products to customers. These recommendations are based on the opinions of other customers.

TEXT BOOKS:
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