Fundamentals of Data Warehouse

Introduction

- A database often contains information or data collection stored electronically.
- Easy to access, manage, modify, update, monitor, and organize data.
- Data is stored in the tables of the database.
- Data warehousing involves consolidating and analyzing data to gain insights.
- Operational systems handle limited data for a limited time.
- Historical data is crucial for high-level operational insights.
- RDBMS emergence in the 1960s led to data warehousing practices.
- Data warehousing became prominent in the late 1980s for decision support systems.

- Customized hardware for data warehouses became available in the late 1990s.
- Well-architected data warehouses provide actionable insights for business decisions.

Evolution of Data Warehouse

- **1980s**: Relational database revolution improved access to valuable information.
- **Late 1980s**: Genesis of modern data warehousing; IBM's 1988 article coined "business data warehouse."
- **Bill Inmon**: Father of Data Warehousing; discussed principles and coined the term.
  - Early 1990s: Formed Prism Solutions; introduced Prism Warehouse Manager.
  - 1992: Published "Building the Data Warehouse."
  - Concept of Corporate Information Factory.
  - Top-down approach, centralized data repository modeled to the third normal form.
- **Ralph Kimball**: Another key figure in Data Warehousing.
  - 1996: Published "The Data Warehouse Toolkit."
  - Bottom-up approach, data marts integrated via Information Bus architecture.
  - Star-schema modeling for easier end-user understanding.

Key Definitions:

- **Inmon's Definition**: "A warehouse is a subject-oriented, integrated, time-variant and non-volatile collection of data in support of management’s decision-making process."
- **Kimball's Definition**: "Data Warehouse (DW) is the conglomerate of all data marts within the enterprise. Information is always stored in the dimensional model."

Data Warehousing and its need

- **Purpose**: Collect and manage data from various sources to provide meaningful business insights.
- **Functions**:
  - Linking and analyzing heterogeneous sources of business data.
  - Central to data collection and reporting framework for BI systems.
  - Stores, filters, retrieves, and analyzes large quantities of organized data.
  - Provides overview and historical data for decision-making.
  - Ensures consistent information across the organization.
  - Offers a flexible and interactive information source.

Need for Data Warehouse

- Enhances turnaround time for analysis and reporting.
- Improves business intelligence and supports decision-making.
- Benefits from historical data for time-period analysis and trend forecasts.
- Standardizes data from heterogeneous sources for easier readability and accessibility.
- Provides a high ROI by enabling quick and informed decision-making.

Benefits of Data Warehouse

- **Scalability**: Easy to scale to match the increase in data volume.
- **Access to Historical Insights**: Allows access to past data for pattern tracing.
- **Flexibility**: Can be built on-premises or on cloud platforms.
- **Efficiency**: Increases business efficiency by providing reliable insights.
- **Data Security**: Centralized data warehouse enables multi-level security.
- **Increased Revenue and Returns**: Access to data analytics strengthens business decisions.
- **Faster and Accurate Data Analytics**: Centralized data allows for quicker and more accurate analysis.

Data Warehouse Design Approaches

Importance

- Selection of the right data warehouse design is crucial.
- It can save significant time and project costs.

Main Approaches

There are two primary design approaches for data warehouses:

1. **Top-Down Approach (Bill Inmon)**
2. **Bottom-Up Approach (Ralph Kimball)**

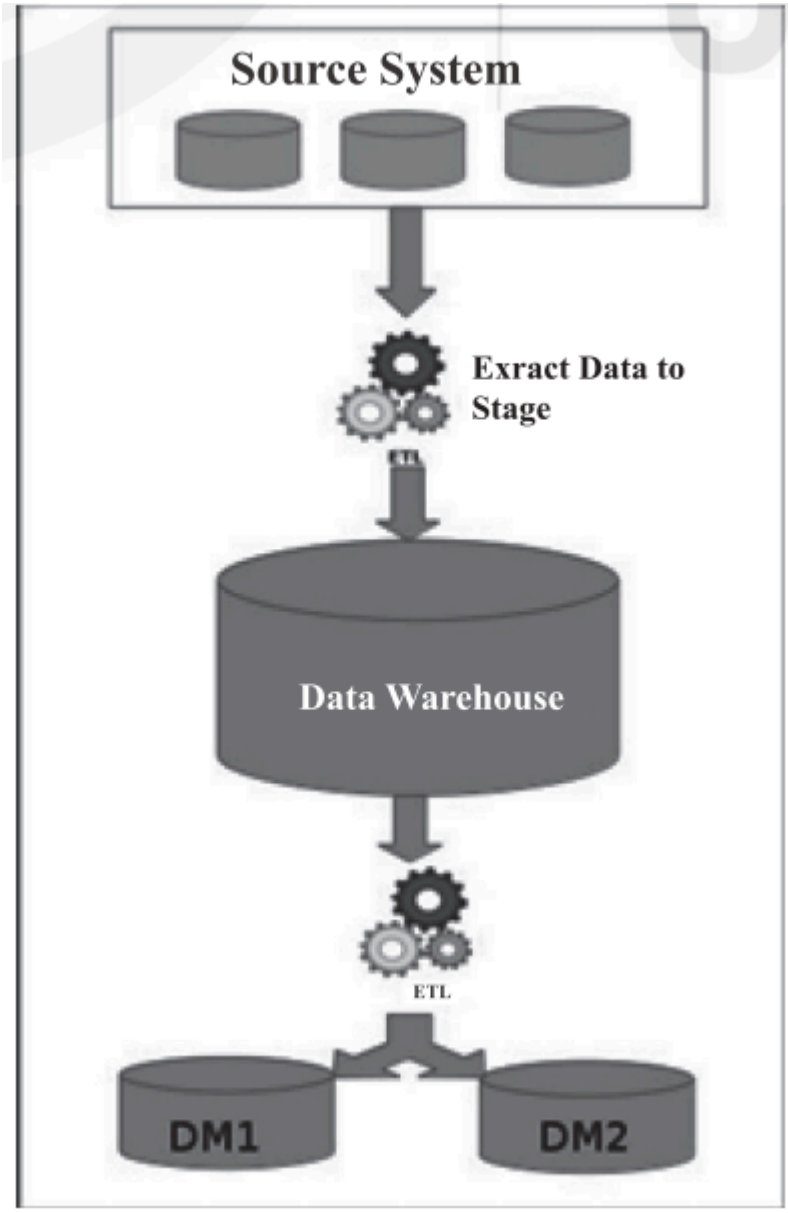
1. Top-Down Approach

Bill Inmon's methodology:

- **Data Warehouse First**: The data warehouse is designed first.
- **Data Marts**: Built on top of the data warehouse.

Steps:

1. **Extract Data to Stage**:
    - Data is extracted from various source systems.
    - Loaded and validated in the staging area using ETL tools.
2. **Aggregation & Summarization**:
    - Extracted data is aggregated and summarized.
    - Loaded back into the data warehouse.
3. **Data Marts**:
    - Data is extracted from the warehouse to data marts.
    - Further transformations are applied as defined by the data marts.



2. Bottom-Up Approach

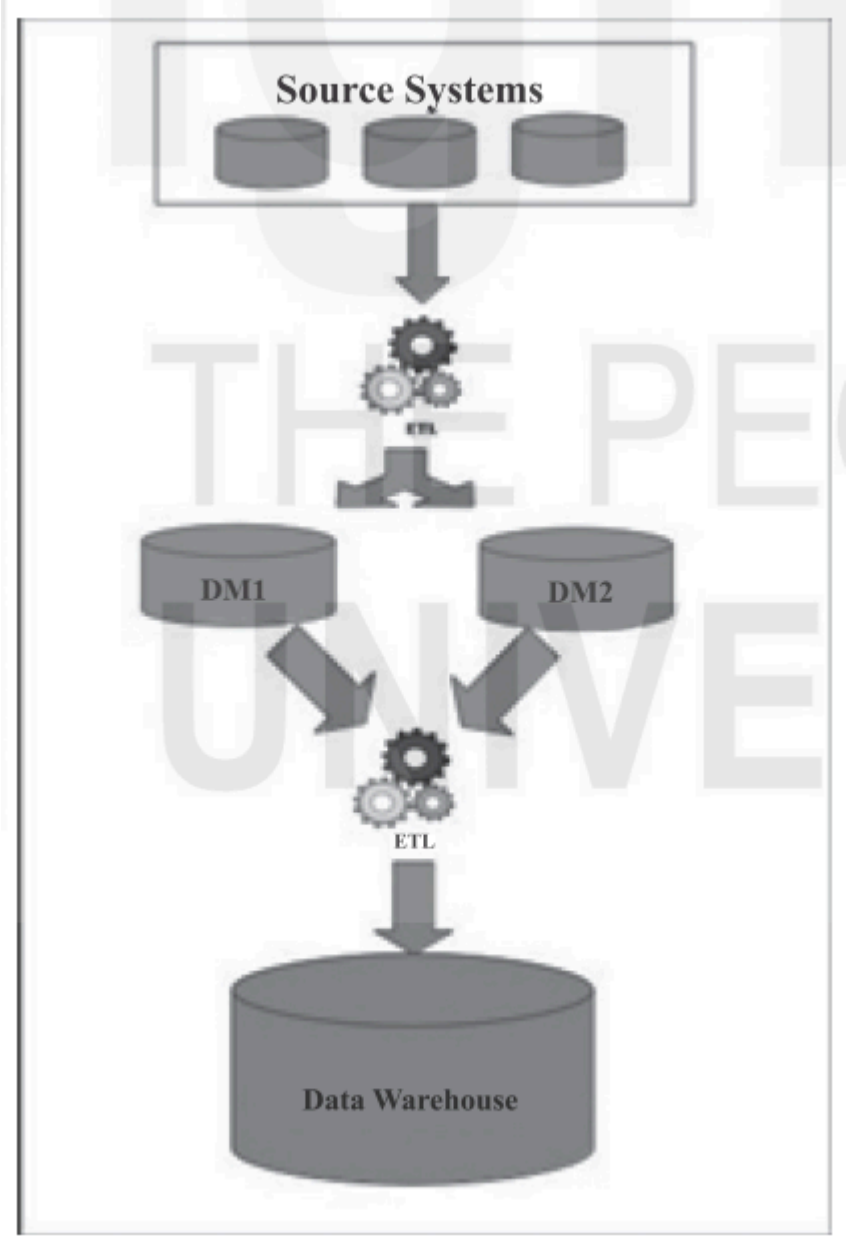
Ralph Kimball's methodology:

- **Dimensional Modelling**: Known as the Kimball methodology.
- **Data Marts First**: Created for specific business processes, then integrated into an enterprise data warehouse (EDW).

Steps:

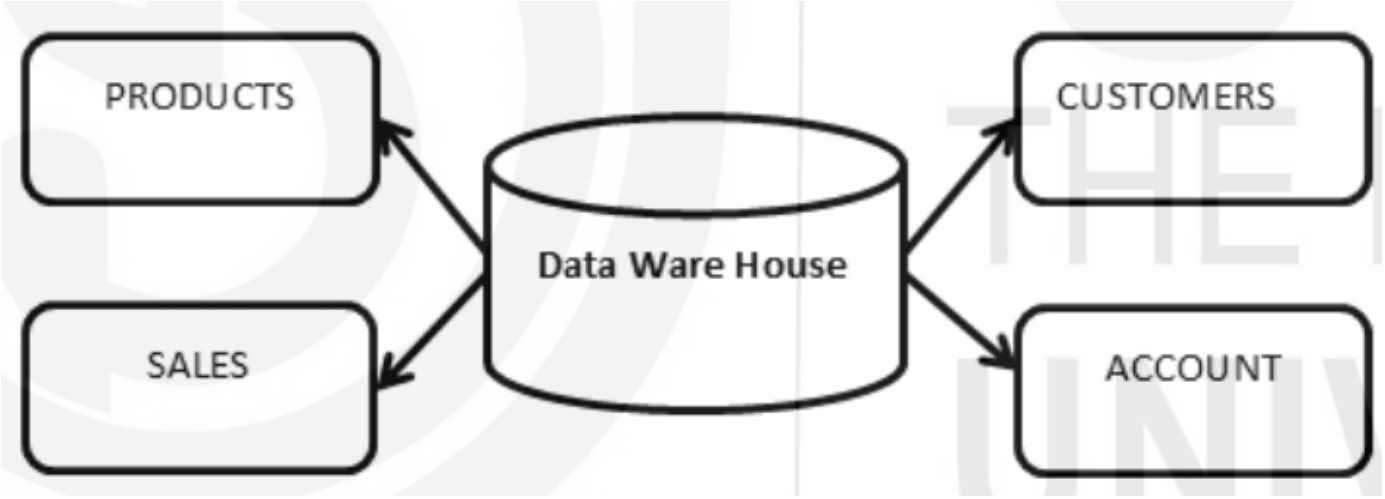
1. **Data Marts Creation**:
   - Data is extracted from source systems into the staging area.
   - Processed and loaded into data marts.
2. **Refresh Data Marts**:
   - Current data is extracted again to the staging area.
   - Transformed and loaded into data marts.
3. **Enterprise Data Warehouse**:

- Aggregated and summarized data from data marts is loaded into the EDW.
- Made available for end-user analysis.

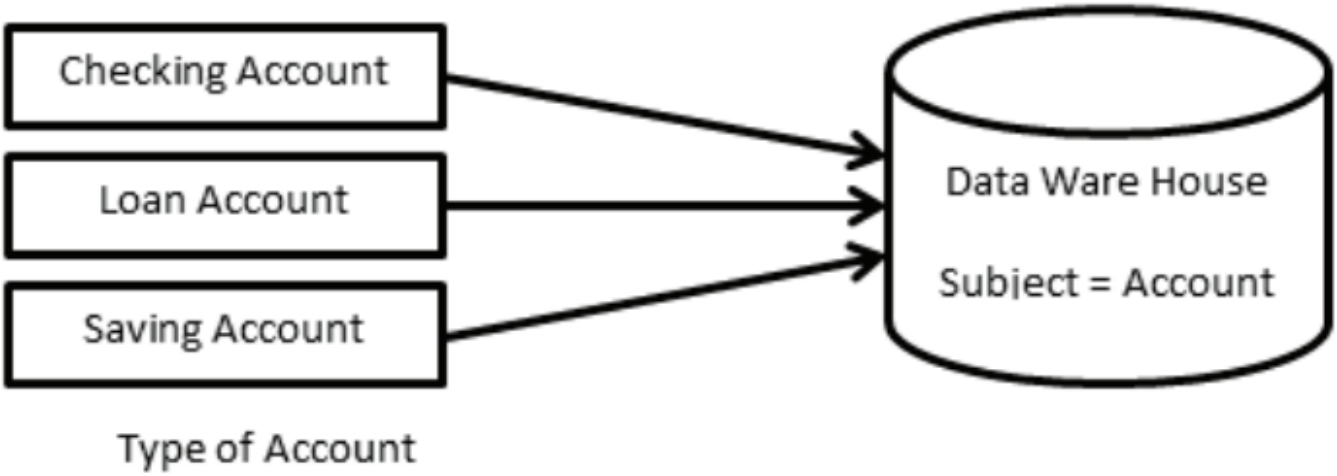


Characteristics of a Data Warehouse

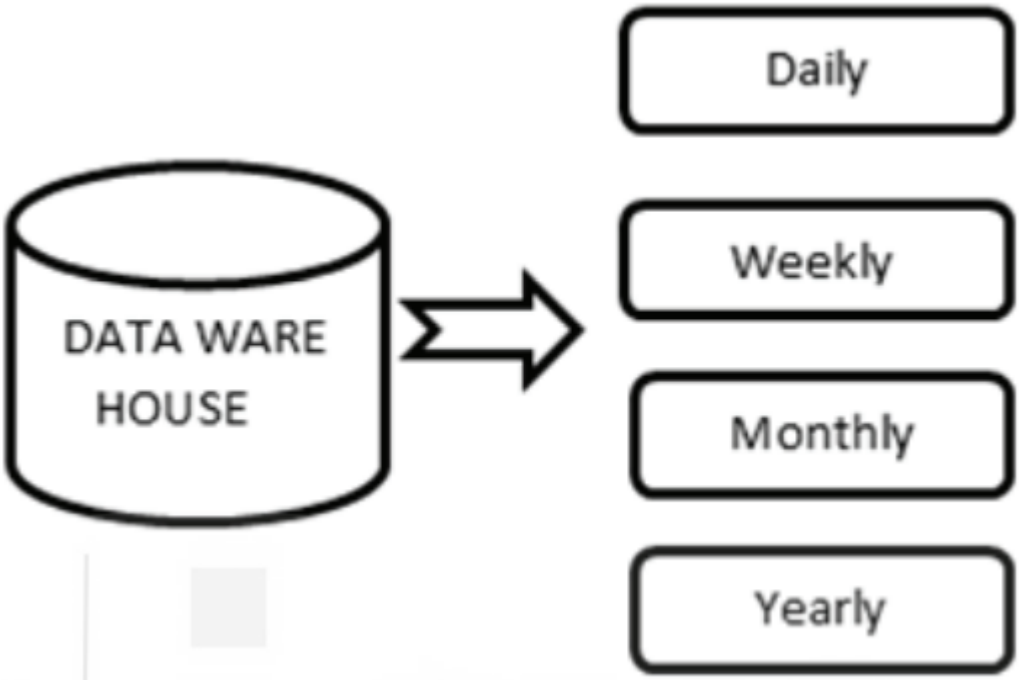
1. **Subject-Oriented**:
   - Focuses on specific themes (e.g., Sales, Products, Customers).
   - Aimed at decision making, not just current operations.



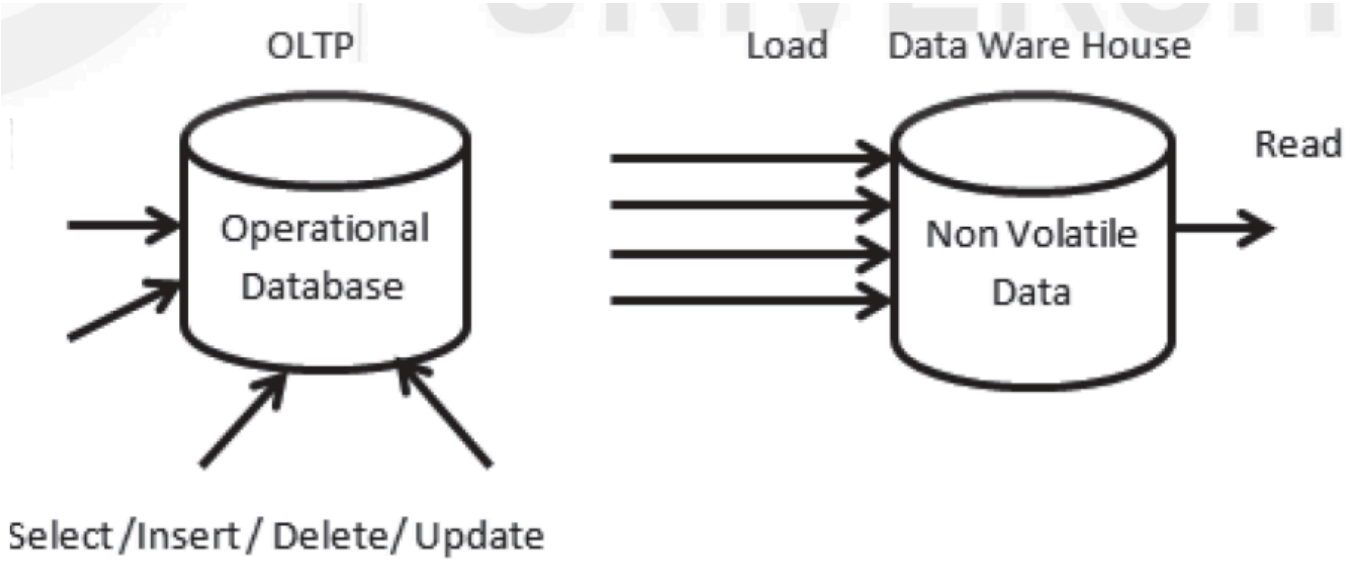
2. **Integrated**:
    - Combines data from various sources into a relational database.
    - Data must be consistent, readable, and coded.



3. **Time-Variant**:
    - Data is stored for specific intervals (weekly, monthly, yearly).
    - Provides historical data for analysis.
    - Data cannot be changed once stored.



4. **Non-Volatile**:
    - Data is permanent and not erased.
    - Separate from the operational database.
    - Manages large amounts of data for analysis.

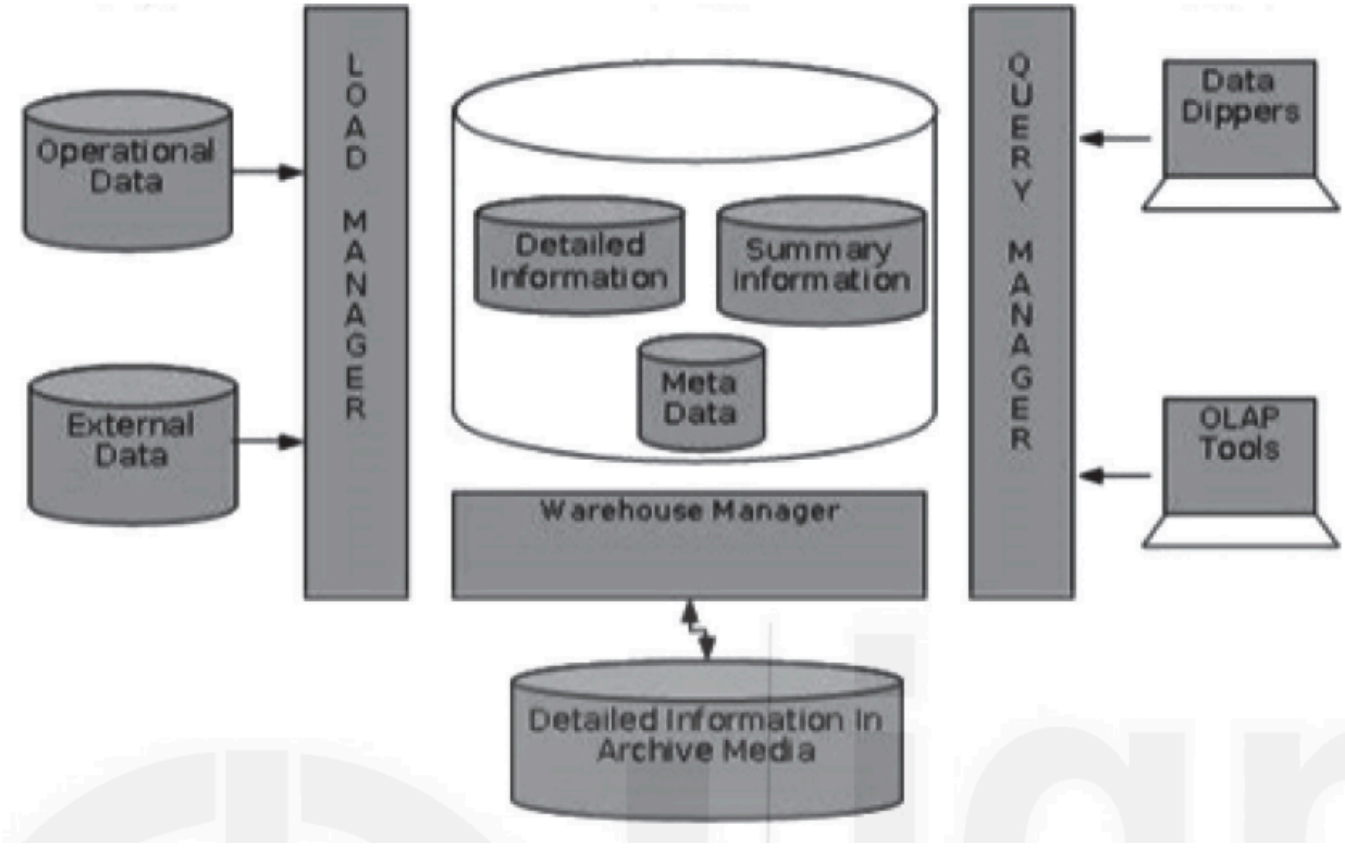


How Data Warehouse Works

- **Central Repository**: Collects data from multiple sources (structured, semi-structured, unstructured).
- **Integration**: Disparate sources are integrated for comprehensive use.
- **Data Mining**: Finds patterns to increase profits.

Components

1. **Load Manager**:
    - Collects data from operational systems.
    - Converts data into a usable form.
    - Tasks: Data identification, validation, extraction, cleansing, formatting, standardization, merging, and establishing integrity.
2. **Warehouse Manager**:
    - Core of the data-warehousing system.
    - Organizes data for easy access and frequent updates.
3. **Query Manager**:
    - Provides access to warehouse information.
    - Uses tools for query, reporting, OLAP, statistics, data discovery, and graphical systems.
4. **End-User Access Tools**:
    - Categories: Reporting Data, Query Tools, Data Dippers, Tools for EIS, Tools for OLAP, Tools for Data Mining.



OLTP and OLAP

Overview

- **OLTP (Online Transaction Processing)**: Captures, stores, and processes real-time transactional data.
- **OLAP (Online Analytical Processing)**: Analyzes aggregated historical data from OLTP systems using complex queries.

Online Transaction Processing (OLTP)

- **Function**: Captures and maintains transaction data in a database.
- **Examples**: Banking activities, credit card transactions, retail checkout.
- **Emphasis**: Fast processing with frequent reads, writes, and updates.
- **Data Integrity**: Built-in system logic ensures data integrity during transaction failures.

Online Analytical Processing (OLAP)

- **Function**: Applies complex queries to large amounts of historical data.
- **Sources**: Data aggregated from OLTP databases and other sources.
- **Purpose**: Used for data mining, analytics, and business intelligence.
- **Emphasis**: Quick response times to complex queries.
- **Examples**: Year-over-year financial performance, marketing trends.
- **Impact of Query Failure**: Does not interrupt customer transactions but can affect business intelligence accuracy.

Key Differences

Characteristics	OLTP	OLAP
Handles	Large number of small transactions	Large volumes of data with complex queries
Query Types	Simple standardized queries	Complex queries
Operations	INSERT, UPDATE, DELETE commands	SELECT commands for data aggregation and reporting
Response Time	Milliseconds	Seconds, minutes, or hours
Design	Industry-specific (e.g., retail, manufacturing, banking)	Subject-specific (e.g., sales, inventory, marketing)
Source	Transactions	Aggregated data from transactions
Purpose	Control and run essential business operations in real time	Plan, solve problems, support decisions, discover insights
Data Updates	Short, fast updates initiated by user	Data periodically refreshed with scheduled batch jobs
Space Requirements	Generally small if historical data is archived	Generally large due to large datasets aggregation
Backup and Recovery	Regular backups for business continuity	Lost data can be reloaded from OLTP database
Productivity	Increases productivity of end users	Increases productivity of managers, analysts, executives
Data View	Lists day-to-day business transactions	Multi-dimensional view of enterprise data

Characteristics	OLTP	OLAP
User Examples	Customer-facing personnel, clerks, online shoppers	Data analysts, business analysts, executives
Database Design	Normalized databases for efficiency	Denormalized databases for analysis

Data Warehouse Fundamentals and Architecture

Data Granularity

- **Granularity**: Refers to the level of detail in data.
  - **Fine Granularity**: Greater detail, less summary.
  - **Gross Granularity**: Fewer details, more summarization.
- **Operational Data**: Stored at the lowest level of information.
  - Example: Sale units stored at the unit level per transaction.
- **Summary Data**: Aggregated data for analysis.
  - Example: Total product orders for a month.
- **Analysis Process**:
  - Starts at a high level of summarization.
  - Drill down to finer details as needed.
- **Storage**: Data at different granularity levels can be maintained effectively.
- **Granularity Levels**: Depend on processing and performance requirements.
  - Example: Yearly, monthly, daily, hourly, minute, second.

Metadata and Data Warehousing

- **Common Schema**: Data stored using a controlled schema.
- **Data Dictionary**: Stores metadata such as:
  - Logical data structures
  - File and address data
  - Index information
- **Metadata Components**:
  - Data structure from the programmer's view
  - Data structure from DSS analysts' view
  - Data warehouse's data sources
  - Data transformation details
  - Data model
  - Connection between data model and data warehouse
  - Data extraction history
- **Importance**:
  - Ensures reporting accuracy
  - Validates data transformation
  - Ensures calculation accuracy
  - Aligns with business terms

Data Warehousing Applications

- **Investment and Insurance**: Analyzes customer and market trends.
- **Healthcare**: Forecasts treatment outcomes and shares data with units like research labs and medical units.
- **Retail**: Supports distribution, marketing, pricing, promotional tracking, and customer trend analysis.
- **Social Media Websites**: Analyzes large data sets for members, groups, and locations.
- **Banking**: Analyzes spending patterns for special offers.
- **Government**: Stores and analyzes taxes to detect theft.
- **Airlines**: Supports operations like crew assignments and flight analysis.
- **Public Sector**: Manages data and records for government agencies.

Types of Data Warehouses

- **Enterprise Data Warehouse**:
  - Central repository for decision support.
  - Stores business information from various sources.
  - Provides a complete overview of objects in the data model.
- **Operational Data Warehouse**:
  - Enterprise-wide scope with near real-time data refresh.
  - Supports routine commercial activities.
  - Data scrubbed and duplication fixed.
- **Data Mart**:
  - Subset of a data warehouse.
  - Supports specific regions, business units, or functions.
  - Enhances user responses and reduces data volume for analysis.

Popular Data Warehouse Platforms

- **Google BigQuery**:
  - Cost-effective with built-in machine learning.
  - Executes queries on petabytes of data for real-time analytics.
  - Ideal for low-cost, quick decision-making.
- **AWS Redshift**:
  - Cloud-based, processes petabytes of data quickly.
  - Supports automatic concurrency scaling.
  - Requires a database administrator for storage efficiency.
- **Snowflake**:
  - Offers options for public cloud technology.
  - Analyzes data from various sources.
  - Dependent on Azure, AWS, and GCS.
- **Microsoft Azure Synapse**:
  - Robust platform for data management and analytics.
  - Supports querying with serverless or provisioned resources.
  - Integrates data warehousing and analytics with a unified experience.

Check Your Progress-1

1. What is a Data Warehouse and why is it important?
2. Mention the characteristics of a Data Warehouse.

Check Your Progress-2

1. Why a data warehouse is separated from Operational Databases?
2. Mention the key differences between a database and a data warehouse.