Lecture 1

Introduction to Database System

Basic Definitions

- Data:
  - Known facts that can be recorded and have an ontornihito implicit meaning.
- Database:
  - A collection of related data which is shu-shong-logno logically coherent and is built for a specific purpose.
- Mini-world:
  - Some part of the real world about which data is stored in a database. For example, student grades and transcripts at a university.
- Database Management System (DBMS):
  - A software package/system to facilitate the creation and maintenance of a computerized database.
- Database system:
  - The DBMS software together with the data itself. Sometimes, the applications are also included.

Example of a Simple Database

STUDENT

Name	Student_number	Class	Major
Smith	17	1	CS
Brown	8	2	CS

COURSE

Course_name	Course_number	Credit_hours	Department
Intro to Computer Science	CS1310	4	CS
Data Structures	CS3320	4	CS
Discrete Mathematics	MATH2410	3	MATH
Database	CS3380	3	CS

GRADE_REPORT

Student_number	Section_identifier	Grade
17	112	B
17	119	C
8	85	A
8	92	A
8	102	B
8	135	A

SECTION

Section_identifier	Course_number	Semester	Year	Instructor
85	MATH2410	Fall	04	King
92	CS1310	Fall	04	Anderson
102	CS3320	Spring	05	Knuth
112	MATH2410	Fall	05	Chang
119	CS1310	Fall	05	Anderson
135	CS3380	Fall	05	Stone

PREREQUISITE

Course_number	Prerequisite_number
CS3380	CS3320
CS3380	MATH2410
CS3320	CS1310

Fig 1: University Database that stores student information, course enrolments and grades

Types of Databases and Database Applications

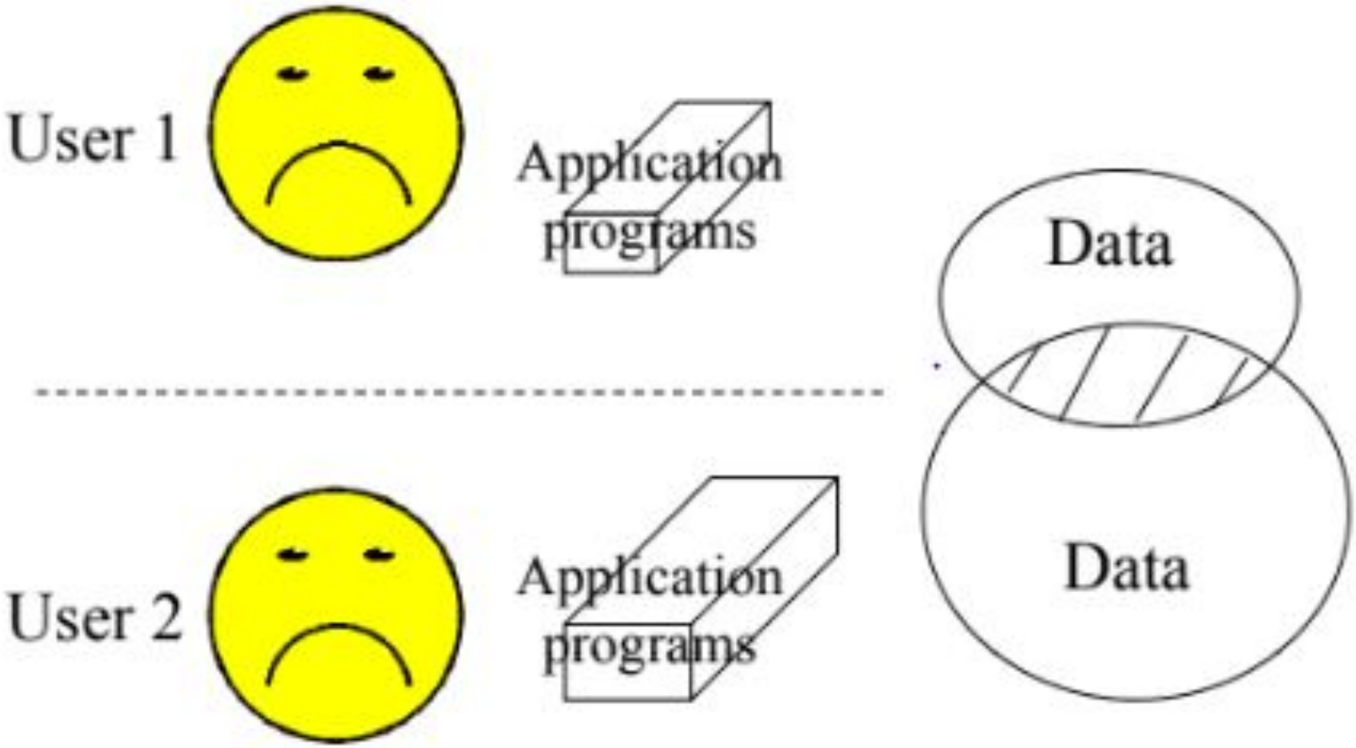
- Traditional applications:
  - Numeric and textual databases
- More recent applications:
  - Multimedia databases
  - Geographic Information Systems (GIS)
  - Biological and genome databases
  - Data warehouses
  - Mobile databases
  - Real-time and active databases

Managing Data

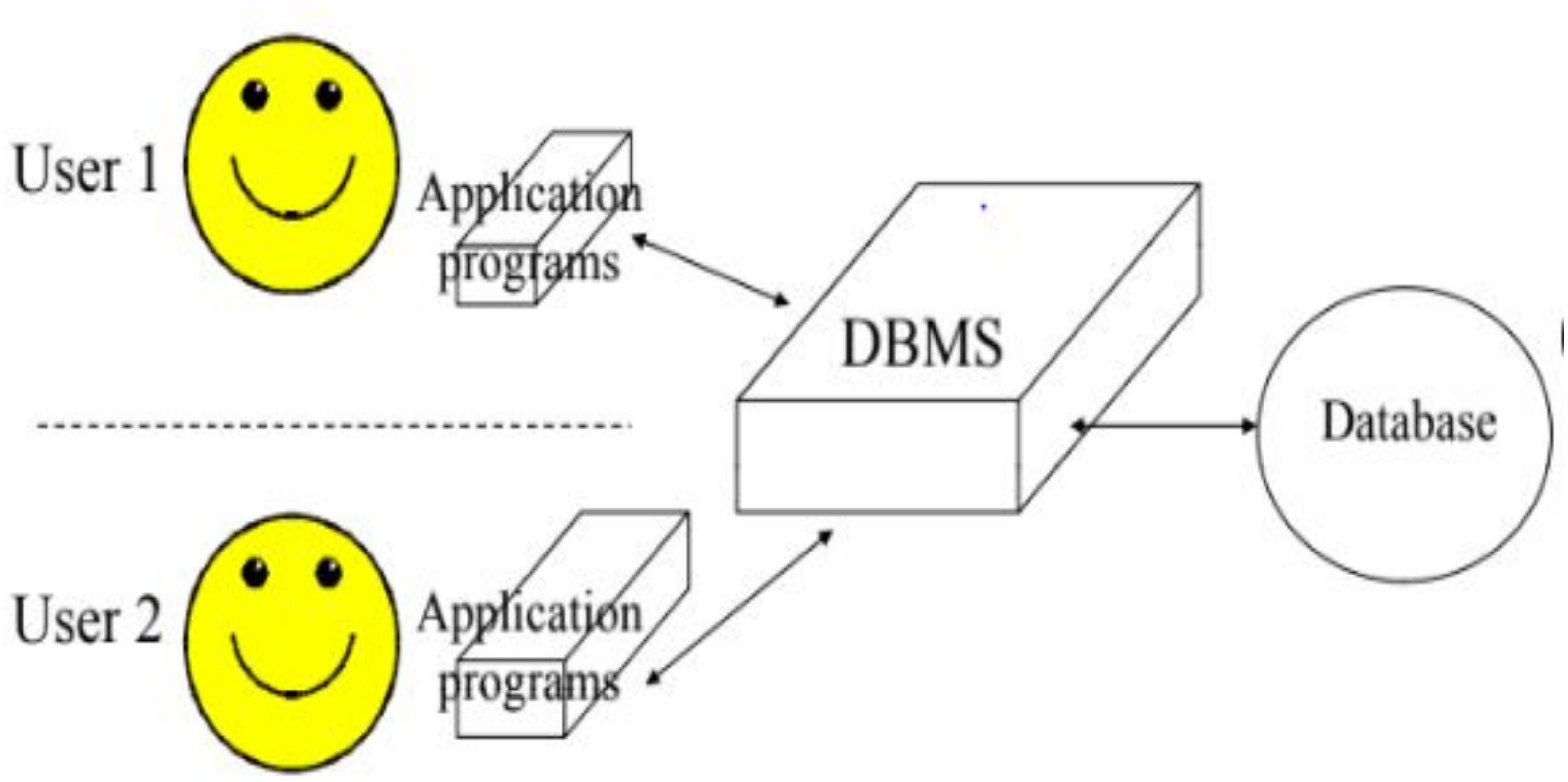
There are two approaches to manage data There are two approaches to manage data:

- **File-based approach:** An approach that utilizes a collection of application programs which performs services to end-users (e.g. Reports). Each program defines and manages its own data.
- **Database approach:** An approach that data is collected and manipulated using specific software called Database Management System, and many programs share this data.

File-Based Approach



Database Approach



A simplified architecture for a database system

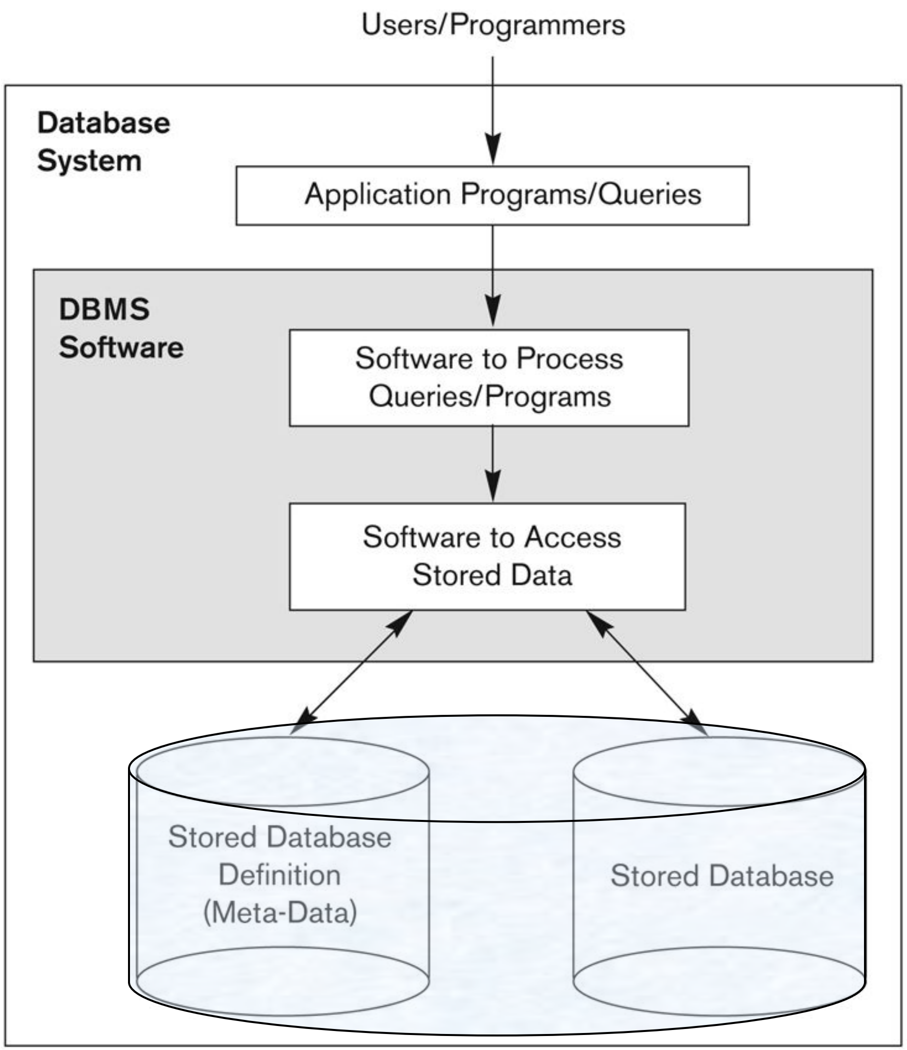


Figure 1.1
A simplified database
system environment.

What a DBMS Facilitates

- *Define* a particular database in terms of its data types,
  a limitation or restriction.
  structures, and constraints
- *Construct* or load the initial database contents on a secondary storage medium
- *Manipulating* the database:
  - Retrieval: Querying, generating reports
  - Modification: Insertions, deletions and updates to its content
  - Accessing the database through Web applications

  Concurrent = existing, happening, or done at the same time.
- *Processing* and *sharing* by a set of concurrent users and application programs – yet, keeping all data valid and consistent

Other DBMS Functionalities

- DBMS may additionally provide:
  - Protection or security measures to prevent unauthorized access
  - "Active" processing to take internal actions on data
  - Presentation and visualization of data
  - Maintenance of the database and associated programs over the lifetime of the database application

Main Characteristics of the Database Approach

- Self-describing nature of a database system:
  - A DBMS **catalog** stores the description of a particular database (e.g. data structures, types, and constraints)
  - The description is called **meta-data**.
  - This allows the DBMS software to work with different database applications.
- Insulation between programs and data:
  - Called **program-data independence**.
  - Allows changing data structures and storage organization without having to change the DBMS access programs

Main Characteristics of the Database Approach (continued)

- Data abstraction:
  - A **data model** is used to hide storage details and present the users with a conceptual view of the database.
- Support of multiple views of the data:
  - Each user may see a different view of the database, which describes **only** the data of interest to that user.

Main Characteristics of the Database Approach (continued)

- Sharing of data and multi-user transaction processing:
  - Allowing a set of **concurrent users** to retrieve from and to update the database.
  - *Concurrency control* within the DBMS guarantees that each transaction is correctly executed or aborted
  - *Recovery* subsystem ensures each completed transaction has its effect permanently recorded in the database or if transaction fails then the database rolls back to the last valid state.
  - OLTP (Online Transaction Processing) is a major part of database applications; allows hundreds of concurrent transactions to execute per second.

Advantages of Using the Database Approach

- Controlling redundancy in data storage and in development and maintenance efforts.
  - Sharing of data among multiple users.
- Restricting unauthorized access to data. Only the DBA staff uses privileged commands and facilities.
- Providing storage structures (e.g. indexes) for efficient query processing.

Advantages of Using the Database Approach (continued)

- Providing optimization of queries for efficient processing
- Providing backup and recovery services
- Providing multiple interfaces to different classes of users
- Representing complex relationships among data
- Enforcing integrity constraints on the database
- Drawing inferences and actions from the stored data using deductive and active rules and triggers

Database Users

- Users may be divided into
  - Those who actually use and control the database content, and those who design, develop and maintain database applications (called "*Actors on the Scene*"), and
  - Those who design and develop the DBMS software and related tools, and the computer systems operators (called "*Workers Behind the Scene*").

Database Users – Actors on the Scene

- Actors on the scene (4 types)
  - Database administrators
    - Responsible for authorizing access to the database, for coordinating and monitoring its use, acquiring software and hardware resources, controlling its use and monitoring efficiency of operations.
  - Database designers
    - Responsible to define the content, the structure, the constraints, and functions or transactions against the database. They must communicate with the end-users and understand their needs.
  - Software Engineers
    - Responsible for implementing the database and its associated applications using a dbms and other programming languages and tools.

Database End Users

- Actors on the scene (continued)
  - End-users: They use the data for queries, reports and some of them update the database content. End-users can be categorized into:
    - Casual: access database occasionally when needed
    - Naïve or parametric: they make up a large section of the end-user population, e.g mobile app and social media users, constantly update and access the database.
    - Sophisticated: business analysts, scientists, engineers, others thoroughly familiar with the system capabilities.
    - Stand-alone: Mostly maintain personal databases using ready-to-use packaged applications.

When not to use a DBMS

- Main inhibitors (costs) of using a DBMS:
  - High initial investment and possible need for additional hardware
  - Overhead for providing generality, security, concurrency control, recovery, and integrity functions
- When a DBMS may be unnecessary:
  - If the database and applications are simple, well defined, and not expected to change
  - If access to data by multiple users is not required
- When a DBMS may be infeasible
  - In embedded systems where a general-purpose DBMS may not fit in available storage

When not to use a DBMS

- When no DBMS may suffice:
  - If there are stringent real-time requirements that may not be met because of DBMS overhead (e.g., telephone switching systems)
  - If the database system is not able to handle the complexity of data because of modeling limitations (e.g., in complex genome and protein databases)
  - If the database users need special operations not supported by the DBMS (e.g., GIS and location-based services).

Data Models

A set of concepts to describe the ***structure*** of a database, the ***operations*** for manipulating these structures, and certain ***constraints*** that the database should obey.

Categories of Data Models

- **Conceptual (high-level, semantic) data models:**
  - Provide concepts that are close to the way many users perceive data.
    - (Also called ***entity-based*** or ***object-based*** data models.)
- **Physical (low-level, internal) data models:**
  - Provide concepts that describe details of how data is stored in the computer. These are usually specified in an ad-hoc manner through DBMS design and administration manuals
- **Implementation (representational) data models:**
  - Provide concepts that fall between the above two, used by many commercial DBMS implementations (e.g. relational data models used in many commercial systems).
- **Self-Describing Data Models:**
  - Combine the description of data with the data values. Examples include XML, key-value stores and some NOSQL systems.

Database Schema versus Database State

- Database Schema:
  - The ***description*** of a database
  - Includes descriptions of the database structure, data types, and the constraints on the database.
- Schema Diagram:
  - An ***illustrative*** display of (most aspects of) a database schema.

- The ***database schema*** changes very infrequently
- **Schema** is also called **intension**.

Example of a Database Schema

STUDENT

Name	Student_number	Class	Major

COURSE

Course_name	Course_number	Credit_hours	Department

PREREQUISITE

Course_number	Prerequisite_number

SECTION

Section_identifier	Course_number	Semester	Year	Instructor

GRADE_REPORT

Student_number	Section_identifier	Grade

Figure 2.1
Schema diagram for the database in Figure 1.2.

Database Schema versus Database State

- Database State:
  - The actual data stored in a database at a ***particular moment in time***. This includes the collection of all the data in the database.
  - Also called database instance (or occurrence or snapshot).

- The ***database state*** changes every time the database is updated.
- **State** is also called **extension**.

Example of a database state

COURSE

Course_name	Course_number	Credit_hours	Department
Intro to Computer Science	CS1310	4	CS
Data Structures	CS3320	4	CS
Discrete Mathematics	MATH2410	3	MATH
Database	CS3380	3	CS

SECTION

Section_identifier	Course_number	Semester	Year	Instructor
85	MATH2410	Fall	04	King
92	CS1310	Fall	04	Anderson
102	CS3320	Spring	05	Knuth
112	MATH2410	Fall	05	Chang
119	CS1310	Fall	05	Anderson
135	CS3380	Fall	05	Stone

GRADE_REPORT

Student_number	Section_identifier	Grade
17	112	B
17	119	C
8	85	A
8	92	A
8	102	B
8	135	A

PREREQUISITE

Course_number	Prerequisite_number
CS3380	CS3320
CS3380	MATH2410
CS3320	CS1310

Figure 1.2
A database that stores student and course information.

Three-Schema Architecture

- Proposed to support DBMS characteristics of:
  - **Program-data independence.**
  - Support of **multiple views** of the data.
- Not explicitly used in commercial DBMS products, but has been useful in explaining database system organization

Three-Schema Architecture

- Defines DBMS schemas at ***three*** levels:
  - **Internal schema** at the internal level to describe physical storage structures and access paths (e.g indexes).
    - Typically uses a **physical** data model.
  - **Conceptual schema** at the conceptual level to describe the structure and constraints for the whole database for a community of users.
    - Uses a **conceptual** or an **implementation** data model.
  - **External schemas** at the external level to describe the various user views.
    - Usually uses the same data model as the conceptual schema.

The three-schema architecture

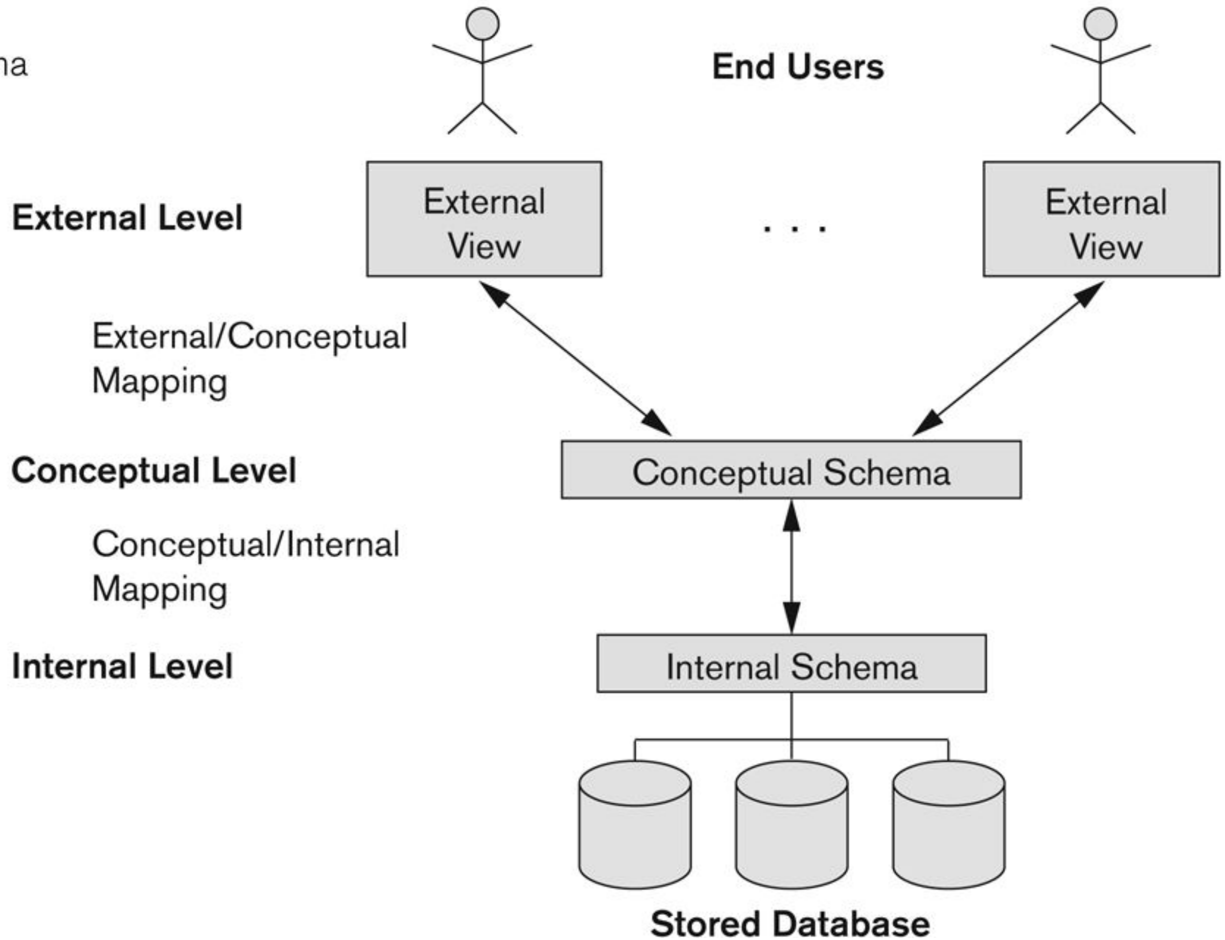


Figure 2.2
The three-schema architecture.

Data Independence

The ability to change the schema at one level without impacting the schema at the next higher level. Two types of data independence:

- **Logical Data Independence:**
  - The capacity to change the conceptual schema without having to change the external schemas and their associated application programs.
  - Example: adding a new column that is not shown in the app or changing the datatype which does not change the external view.
- **Physical Data Independence:**
  - The capacity to change the internal schema without having to change the conceptual schema.
  - For example, the internal schema may be changed when certain file structures are reorganized or new indexes are created to improve database performance

DBMS Languages

- **Data Definition Language (DDL):** Used to define database schemas. The ddl statement is used to identify the description of a schema construct and store the schema description in the DBMS catalog. Creating/Deleting a table, Adding columns, Changing data types are examples that require DDL statements.

- **Data Manipulation Language (DML):** Used to manipulate data by inserting, deleting, updating and retrieving data. DML commands can be *embedded* in a general-purpose programming language such as Java. Two types of DML: high-level/non-procedural and low-level/procedural.

DBMS Interfaces

- Stand-alone query language interfaces
  - Example: Entering SQL queries at the DBMS interactive SQL interface (e.g. SQL*Plus in ORACLE)
- Programmer interfaces for embedding DML in programming languages
- User-friendly interfaces
  - Menu-based, forms-based, graphics-based, natural language interfaces, etc.
- Mobile Interfaces:interfaces allowing users to perform transactions using mobile apps
- Parametric interfaces, e.g., bank tellers using function keys.
- Interfaces for the DBA.