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Faculty of Natural and Mathematical Sciences

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KING'S College LONDON

4CCS1DBS – Database Systems

Week 1 – Introduction to Databases and their Use

Topic: General Concepts on Database Functionality

Week 1 – Learning Outcomes

- An introduction to databases
- Understand the use of database systems
- Terminology, main definitions
- Database architectures, data models

Part 1 – Databases and Database Use

- Types of Databases and Database Applications
- Basic Definitions
- Typical DBMS Functionality
- Example of a Database (UNIVERSITY)
- Main Characteristics of the Database Approach
- Advantages of Using the Database Approach
- When Not to Use Databases

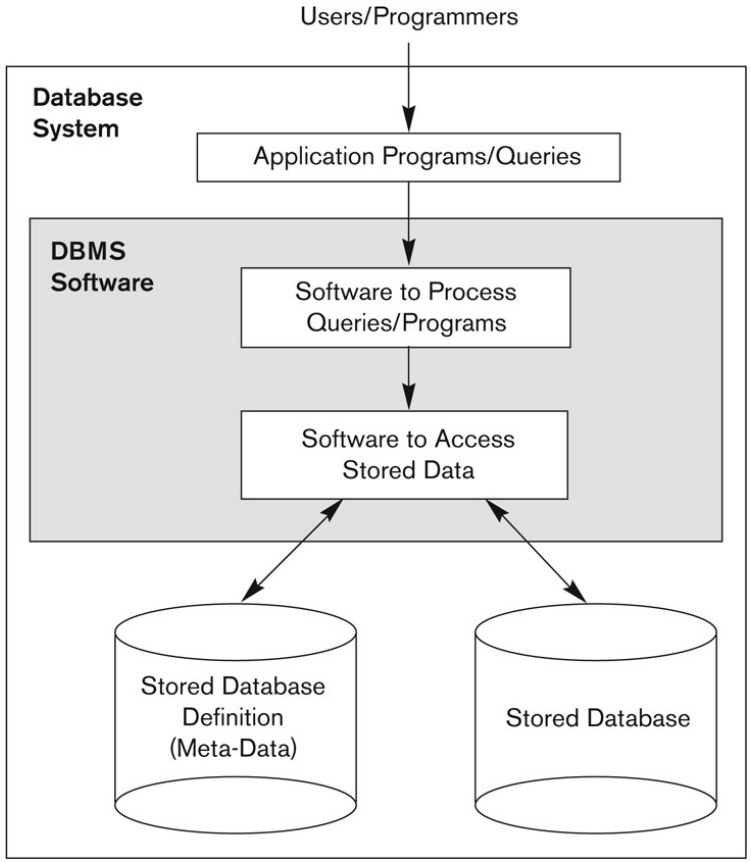
Types of Databases and Database Applications

- Traditional Applications:
  - Numeric and Textual Databases
- More Recent Applications:
  - Multimedia Databases
  - Geographic Information Systems (GIS)
  - Data Warehouses
  - Real-time and Active Databases

Basic Definitions

- **Database**
  - A collection of related data.
- **Data**
  - Known facts that can be recorded and have an implicit meaning.
- **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 computerised database.
- **Database System**
  - The DBMS software together with the data itself. Sometimes applications are also included.

Simplified Database System Environment



Typical DBMS Functionality

- *Define* a particular database in terms of its data types, 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
- *Processing* and *Sharing* by a set of concurrent users and application programs – yet, keeping all data valid and consistent

Typical DBMS Functionality

Other features:

- Protection or Security measures to prevent unauthorised access
- "Active" processing to take internal actions on data
- Presentation and Visualisation of data
- Maintaining the database and associated programs over the lifetime of the database application
  - Called database, software, and system maintenance

Example: Database with Conceptual Data Model

Mini-world for the example:

Part of a UNIVERSITY environment.

Some mini-world *entities*:

STUDENTs

COURSEs

SECTIONs (of COURSEs)

(academic) DEPARTMENTs

INSTRUCTORs

Example: Database with Conceptual Data Model

Some mini-world *relationships*:

SECTIONS *are of specific* COURSES

STUDENTS *take* SECTIONS

COURSES *have prerequisite* COURSES

INSTRUCTORS *teach* SECTIONS

COURSES *are offered by* DEPARTMENTS

STUDENTS *register in* DEPARTMENTS

Note: The above entities and relationships are typically expressed in a conceptual data model, such as the ENTITY-RELATIONSHIP data model (discussed next week)

Example of a Simple Database

UNIVERSITY database that stores student and course data in a

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

SECTION

Section_identifier	Course_number	Semester	Year	Instructor
85	MATH2410	Fall	07	King
92	CS1310	Fall	07	Anderson
102	CS3320	Spring	08	Knuth
112	MATH2410	Fall	08	Chang
119	CS1310	Fall	08	Anderson
135	CS3380	Fall	08	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

Main Characteristics of the Database Approach

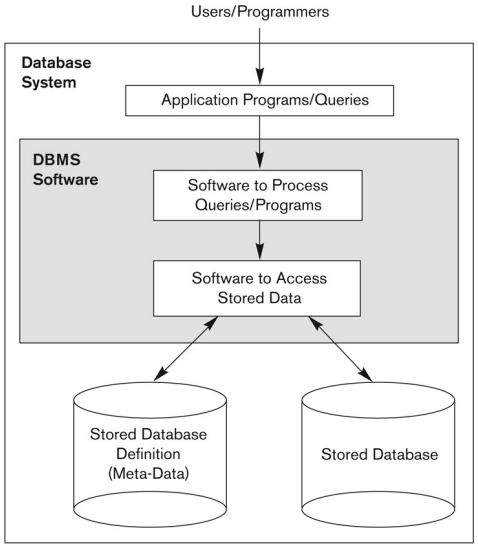
Self-describing nature of a database system:

A DBMS **catalog** stores the definition of a particular database (e.g. data structures, types, constraints, views, value ranges, etc)

The description/Definitions is called **meta-data**.

Separation between programs and data:

Called **program-data independence**.



Example of a Simplified Database Catalog

Data

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Name	Student_number	Class	Major
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Brown	8	2	CS

COURSE

Course_name	Course_number	Credit_hours	Department
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Catalog (meta-data)

RELATIONS

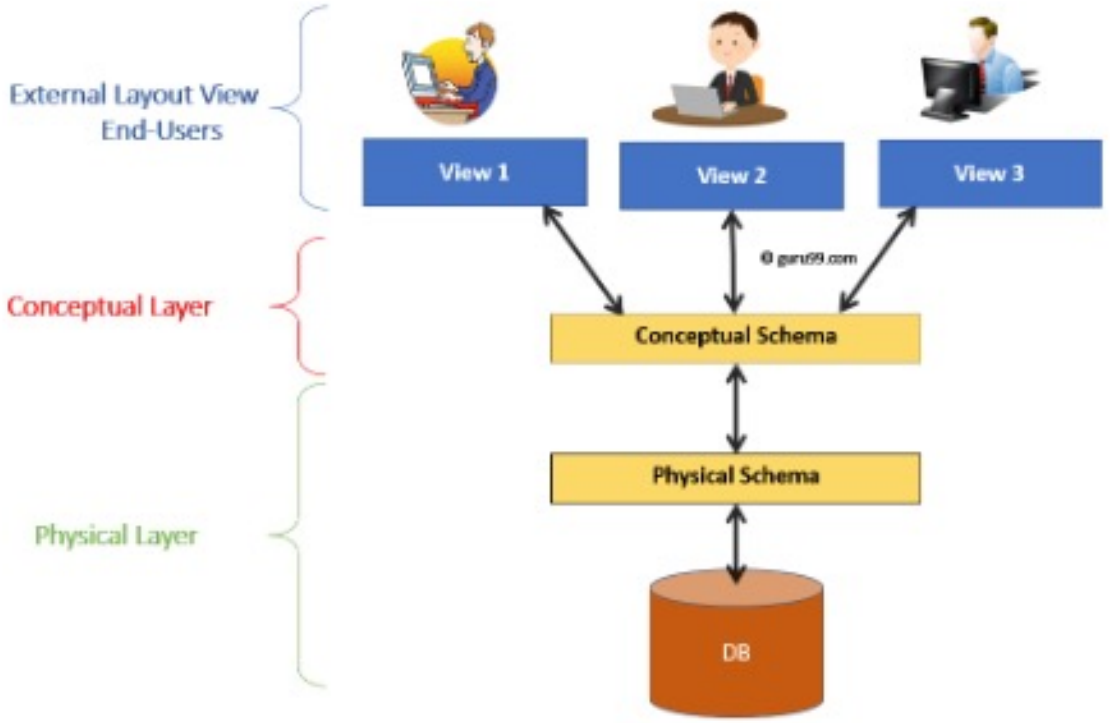
Relation_name	No_of_columns
STUDENT	4
COURSE	4
SECTION	5
GRADE_REPORT	3
PREREQUISITE	2

COLUMNS

Column_name	Data_type	Belongs_to_relation
Name	Character (30)	STUDENT
Student_number	Character (4)	STUDENT
Class	Integer (1)	STUDENT
Major	Major_type	STUDENT
Course_name	Character (10)	COURSE
Course_number	XXXXNNNN	COURSE
….	….	…..
….	….	…..
….	….	…..
Prerequisite_number	XXXXNNNN	PREREQUISITE

Main Characteristics of the Database Approach

- **Data Abstraction:**
- **Support of multiple views of the data**



Main Characteristics of the Database Approach

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
- **OLTP** (Online Transaction Processing) is a major part of database applications.
  - This allows hundreds of concurrent transactions to execute per second.

Advantages of Using Databases

Additional advantages of Using Databases

- Flexibility to change data structures
- Availability of current information
- Economies of scale

When NOT to use a DBMS

- Main inhibitors (costs) of using a DBMS
- When a DBMS may be unnecessary
- When the DBMS may not suffice

Summary of Part 1

- Types of Databases and Database Applications
- Basic Definitions
- Typical DBMS Functionality
- Example of a Database (UNIVERSITY)
- Main Characteristics of the Database Approach
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Week 1 Part 2 – Introduction to Databases and their Use

Topic: Data models and Principles of Database Architecture

Part 2 : Database System Concepts and Architecture

Data Models and their Categories

Database Schema and Database State

Three-Schema Architecture

Database Implementation

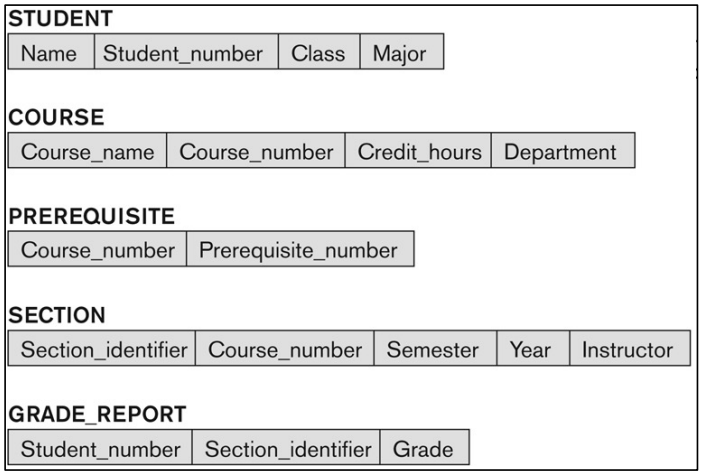
DBMS Languages, Centralised and Client-Server Architectures, Classification of DBMS

Data Models

So what is a Data Model?

Data Model Structure and Constraints:

- Constructs are used to define the database structure
- Constructs typically include ***elements*** (and their ***data types***) as well as groups of elements (e.g. ***entity, record, table***), and ***relationships*** within such groups
- Constraints specify some restrictions on valid data; these constraints must be enforced at all times



Data Models

Data Model Operations:

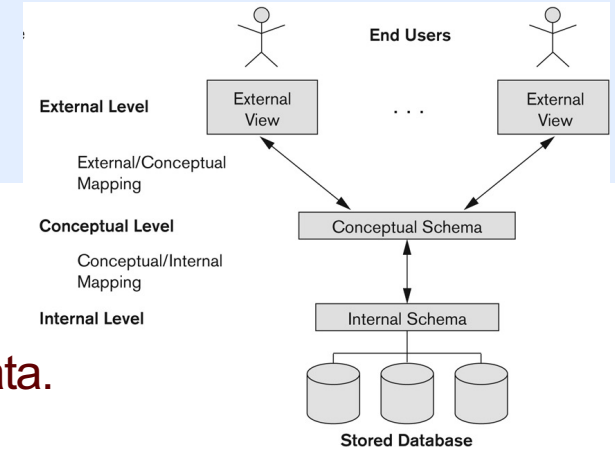
These operations are used for specifying database *retrievals* and *updates* by referring to the constructs of the data model.

Operations on the data model may include

basic model operations (e.g. generic insert, delete, update)

user-defined operations (e.g. compute_student_gpa, update_inventory)

Categories ~~Types~~ of Data Models



Conceptual (high-level, semantic) data models:

Provide concepts that are close to the way many users perceive data.

Physical (low-level, internal) data models:

Provide concepts that describe details of how data is stored in the computer.

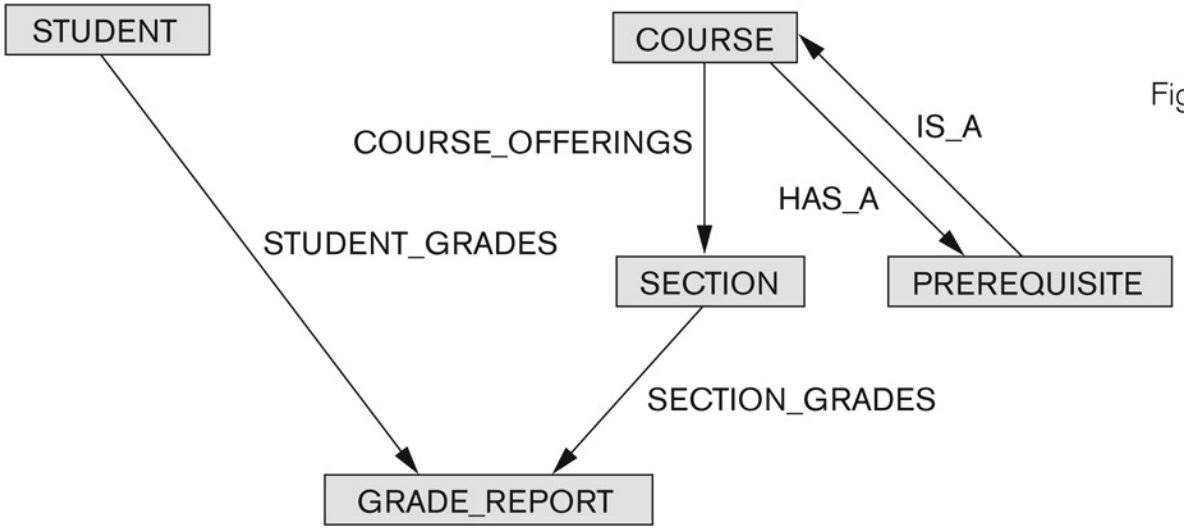
Implementation (representational) data models:

Provide concepts that fall between the above two, used by many commercial DBMS implementations (e.g. relational data models used in many commercial systems).

Types of Data Models

- Relational Model
- Network Model
- Hierarchical Model
- Object-oriented Data Models
- Object-Relational Models

Example of Network Model Schema



Network Model

Advantages:

- Network Model is able to model complex relationships
- Can handle most situations for modeling using record types and relationship types.
- Language is navigational; uses constructs like FIND, FIND member, FIND owner, FIND NEXT within set, GET, etc.
  - Programmers can do optimal navigation through the database.

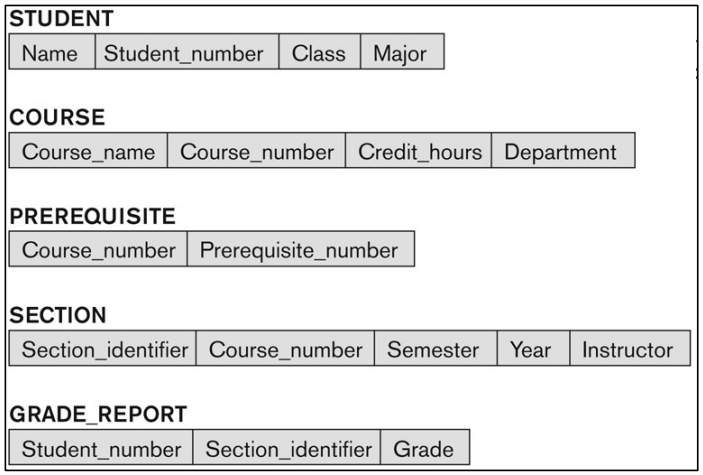
Disadvantages:

- Navigational and procedural nature of processing - Combersome
- Database contains a complex array of pointers that thread through a set of records.
  - Little scope for automated “query optimisation”

The Relational Data Model

Relational Model:

- Proposed in 1970 by E.F. Codd (IBM), first commercial system in 1981-82.
- Appears in several commercial products (e.g. DB2, ORACLE, MS SQL Server, SYBASE, INFORMIX).
- Several free open source implementations, e.g. MySQL, PostgreSQL
- Currently most dominant for developing database applications



Database Schema

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.

Schema Construct:

- A ***component*** of the schema or an object within the schema, e.g., STUDENT, COURSE.

Example of a Database Schema

STUDENT

Name	Student_number	Class

Schem
datab

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

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 term *instance* is also applied to individual database components, e.g. *record instance, table instance, entity instance*

Refers to the ***content*** of a database at a moment in time.

Initial Database State: refers to the database state when it is initially loaded into the system.

Valid State: a state that satisfies the structure and constraints of the database.

Example of a Database State

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Database *Schema* vs. Database *State*

Distinction

The ***database schema*** changes infrequently.

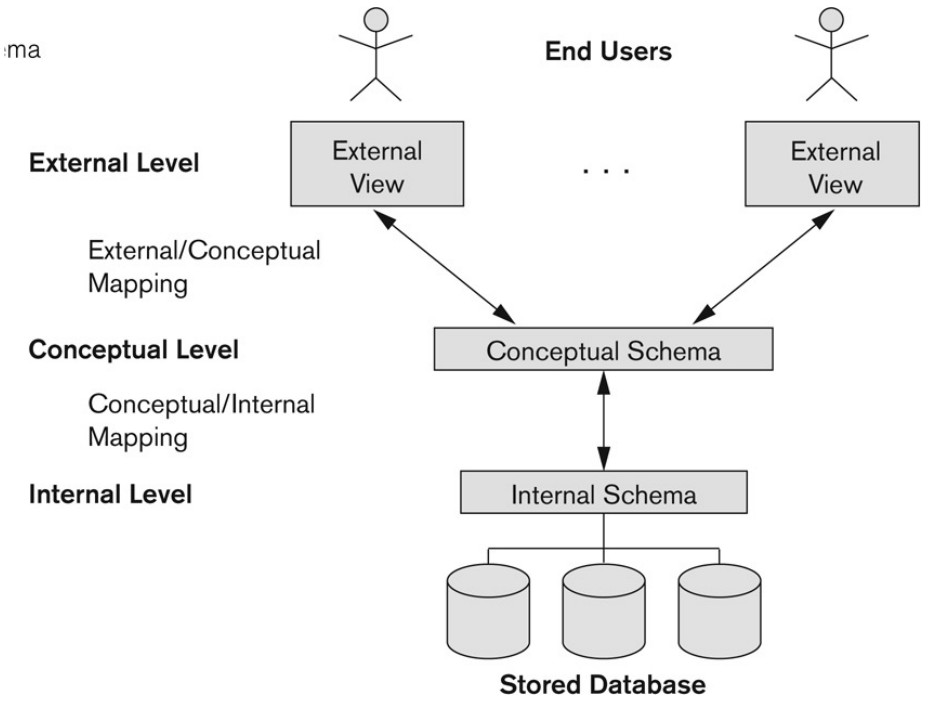
The ***database state*** changes every time the database is updated.

Schema is also called **intension**.

State is also called **extension**.

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 organisation



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.

Three-Schema Architecture

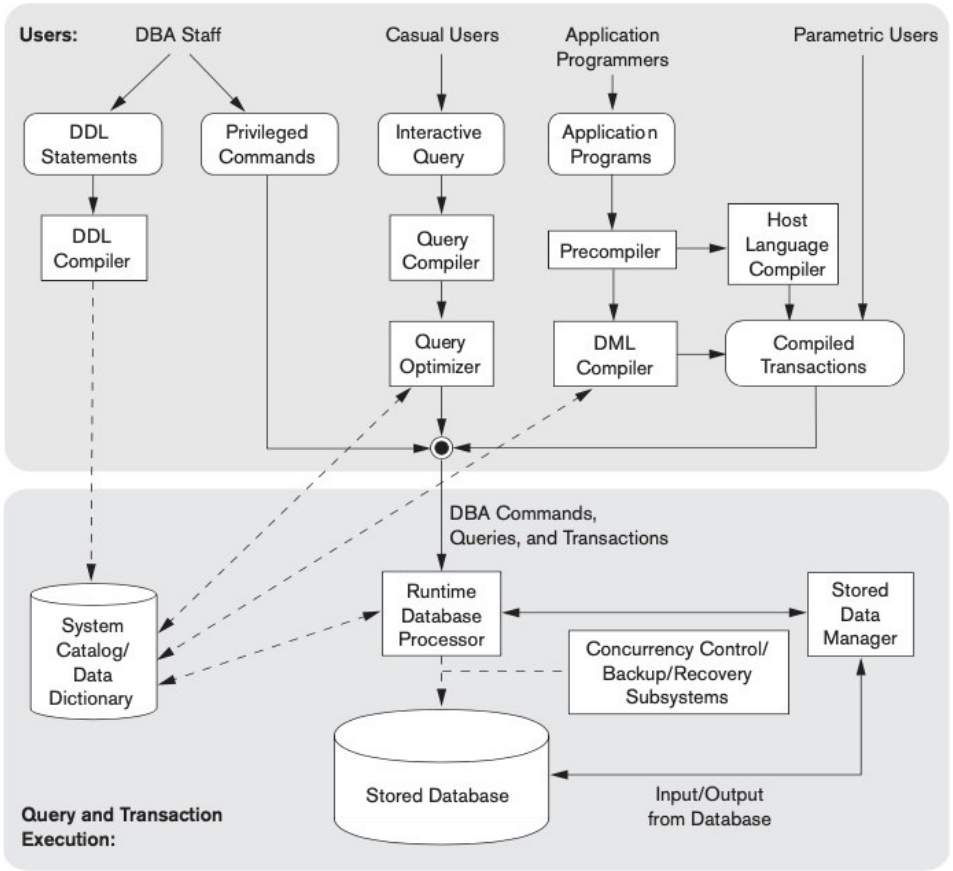
Mappings among schema levels are needed to transform requests and data.

- Programs refer to an external schema and are mapped by the DBMS to the internal schema for execution.
- Data extracted from the internal DBMS level is reformatted to match the user's external view (e.g. formatting the results of an SQL query for display in a Web page)

Components of a Database

Users and related database environment

Data storage and transaction processing by DBMS



DBMS Languages

- Data Definition Language (DDL)
  - Specify conceptual and internal schemas
- Data Manipulation Language (DML)
  - Used to query and manipulate the database
    - High-Level or Non-procedural Languages: These include the relational language SQL
      - May be used in a standalone way or may be embedded in a programming language
    - Low Level or Procedural Languages:
      - These must be embedded in a general-purpose programming language

DBMS Languages

Data Definition Language (DDL):

Used by the DBA and database designers to *specify* the conceptual schema of a database.

In some DBMSs, separate **storage definition language (SDL)** and **view definition language (VDL)** are used to define internal and external schemas. SDL is typically realised via DBMS commands provided to the DBA and database designers

DBMS Languages

Data Manipulation Language (DML):

Used to specify database *retrievals* and *updates*

DML commands (data sub-language) can be *embedded* in a general-purpose programming language (host language), such as C, C++, or Java.

A library of functions can also be provided to access the DBMS from a programming language

Alternatively, stand-alone DML commands can be applied directly (called a *query language*).

Centralised and Client-Server DBMS Architectures

Centralised DBMS:

- Combines everything into single system including, DBMS software, hardware, application programs, and user interface processing software.
- User can still connect through a remote terminal – however, all processing is done at centralised site.

Three Tier Client-Server Architecture

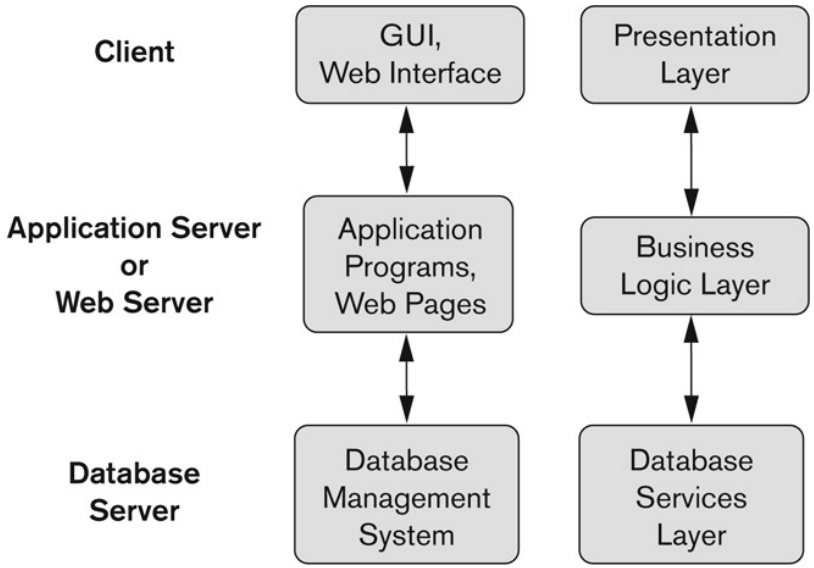
Common for Web applications

Intermediate Layer called Application Server or Web Server:

- Stores the web connectivity software and the business logic part of the application used to access the corresponding data from the database server
- Acts like a conduit for sending partially processed data between the database server and the client.

Three-Tier Architecture Can Enhance Security:

- Database server only accessible via middle tier
- Clients cannot directly access database server



Classification of DBMSs

- Based on the type of data model used
  - Traditional: Relational, Network, Hierarchical
  - Emerging: Object-oriented, Object-relational
- Other classifications
  - Single-user (typically used with personal computers) vs. multi-user (most DBMSs)
  - Centralised (uses a single computer with one database) vs. distributed (uses multiple computers, multiple databases)

Variations of Distributed DBMSs (DDBMSs)

- Homogeneous DDBMS
  - Same DBMS in all sites
- Heterogeneous DDBMS
  - Several autonomous DBMS software at multiple sites, connected through network
- Federated or Multidatabase Systems
  - DBMSs loosely coupled, have some autonomy

Summary of Part 2

Data Models and their Categories

Database Schemas, States

Three-Schema Architecture

Database Implementation

- DBMS Languages, Centralised and Client-Server Architectures, Classification of DBMS

Next week: Data modelling through Entity-Relationship diagrams