Database Management Systems

ICT1212

Database System Concepts & Architectures

Department of ICT
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Lecture 02

What we discuss Today……

- Summery of Database Context
- Data Models and Their Categories
- Schemas, Instances, and States
- Three-Schema Architecture
- Data Independence
- DBMS Languages and Interfaces
- Database System Utilities and Tools
- Database System Environment
- Centralized and Client-Server Architectures
- Classification of DBMSs
- History of Data Models

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 computerized database.
- **Database System:** The DBMS software together with the data itself. Sometimes, the applications are also included.

Typical DBMS Functionality

- **Define a database** : in terms of data types, structures and constraints
- **Construct or Load the Database** on a secondary storage medium
- **Manipulating the database** : querying, generating reports, insertions, deletions and modifications to its content
- **Concurrent Processing** and Sharing by a set of users and programs – yet, keeping all data valid and consistent
- **Protection or Security** measures to prevent unauthorized access
- **Presentation and Visualization** of data

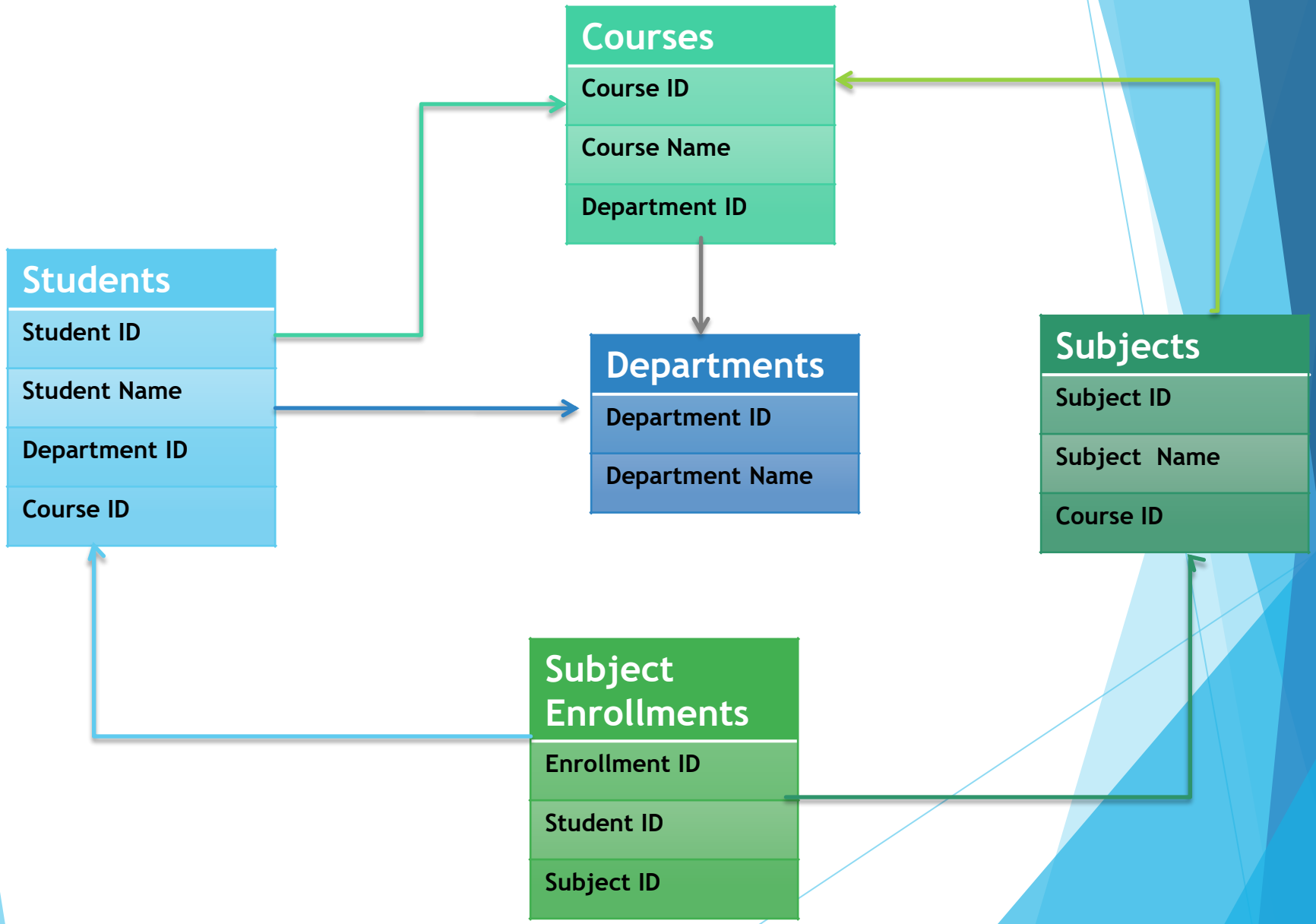
Example of a Database

- **Mini-world for the example: Part of a** UNIVERSITY environment.
- **Some mini-world *entities:***
  - STUDENTs
  - COURSEs
  - SUBJECTs (of COURSEs)
  - (academic) DEPARTMENTs
  - LECTURERs

Example of a Database

- **Some mini-world *relationships*:**
  - SUBJECTs *are of specific COURSEs*
  - STUDENTs *take SUBJECTs*
  - LECTURERs *teach SUBJECTs*
  - COURSEs *are offered by DEPARTMENTs*
  - STUDENTs *major in DEPARTMENTs*

Example of a Database



Database System Concepts & Architectures

Data Models

- **Data Model:**
  - 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.
- **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*** among such groups
  - Constraints specify some restrictions on valid data; these constraints must be enforced at all times

Data Models (continued)

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

Examples of User Defined Operations

- Calculate Final Marks

  10% Quizes + 20% Assessments + 70% Final Exam

- Calculate GPA

  Sum(Result * GPV * No. of Credits)/Sum(Credits)

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

Categories of Data Models

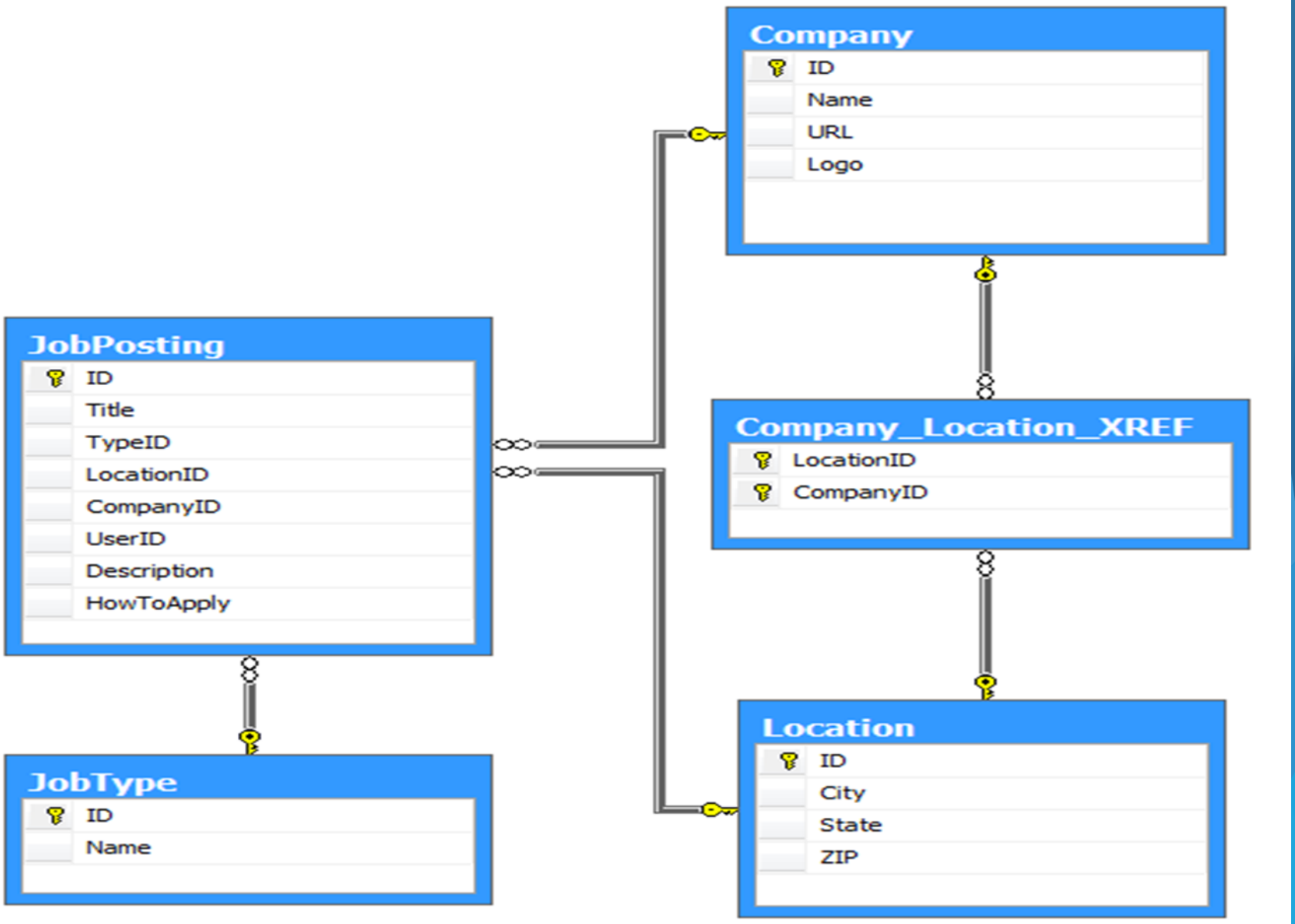
- **Implementation (representational) data models:**
  - Provide concepts that fall between the above two, used by many commercial DBMS implementations (e.g. relational data models used in many commercial systems).

- **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

- 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.

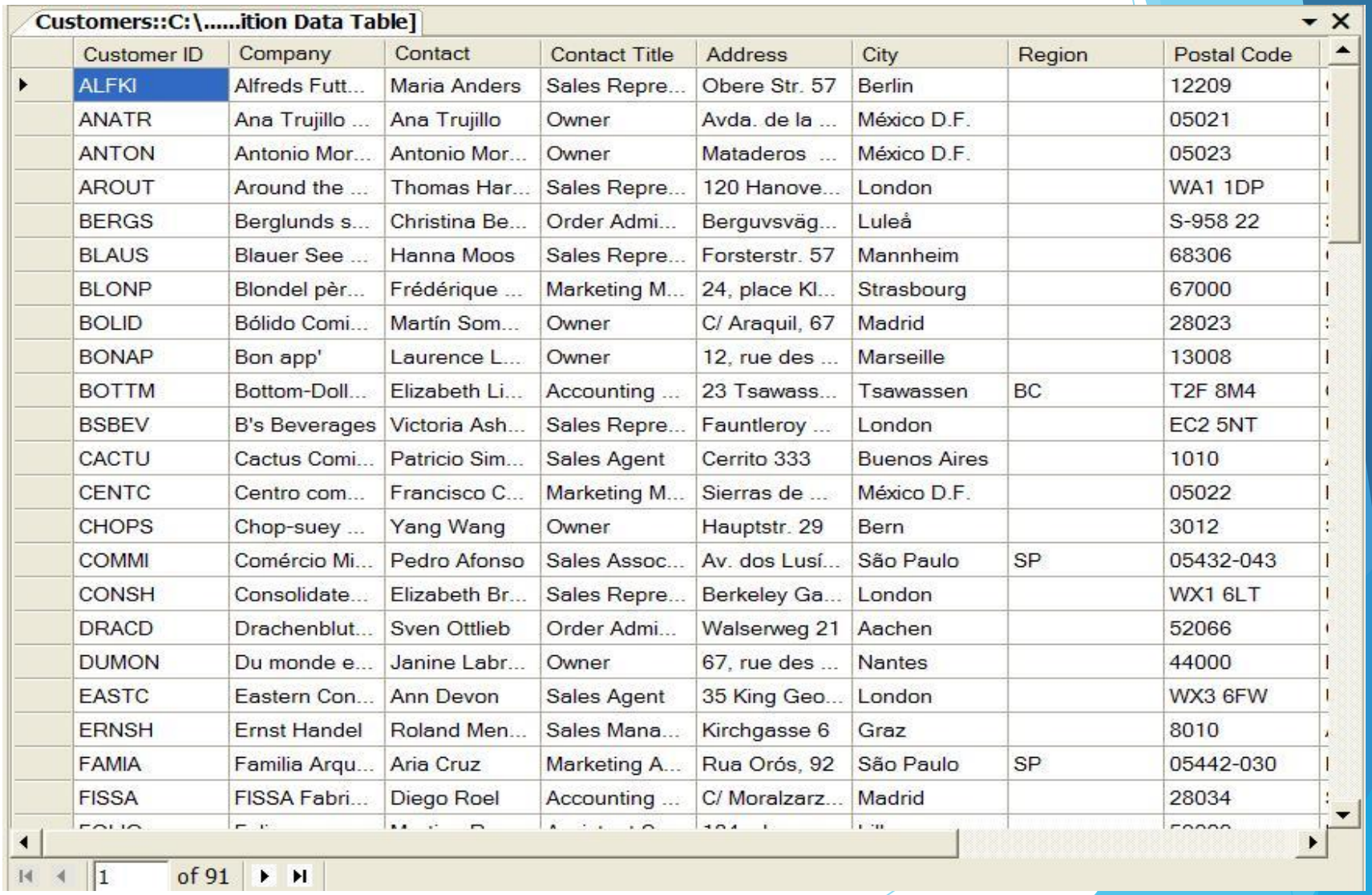
Example of a Database Schema



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*

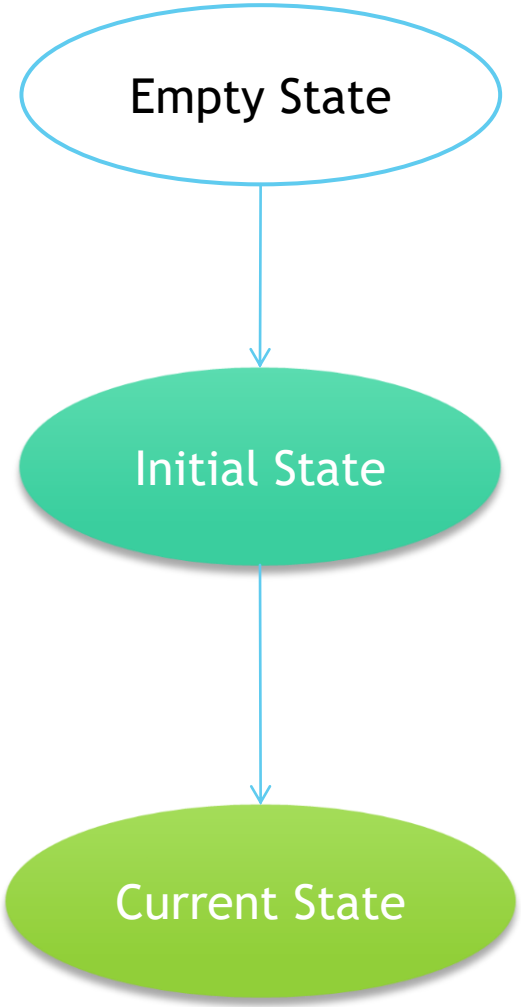
Example of Database Instance



Database State

- Database State:
  - Refers to the ***content*** of a database at a moment in time.
- Empty State
  - Refers to the database state when it is first created (before loading any data)
- 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.

States of a Database



Database Schema vs. Database State

- Distinction
  - The ***database schema*** changes very infrequently.
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  - The ***database state*** changes every time the database is updated.

- **Schema** is also called **intension.**
- **State** is also called **extension.**

Three-Schema Architecture

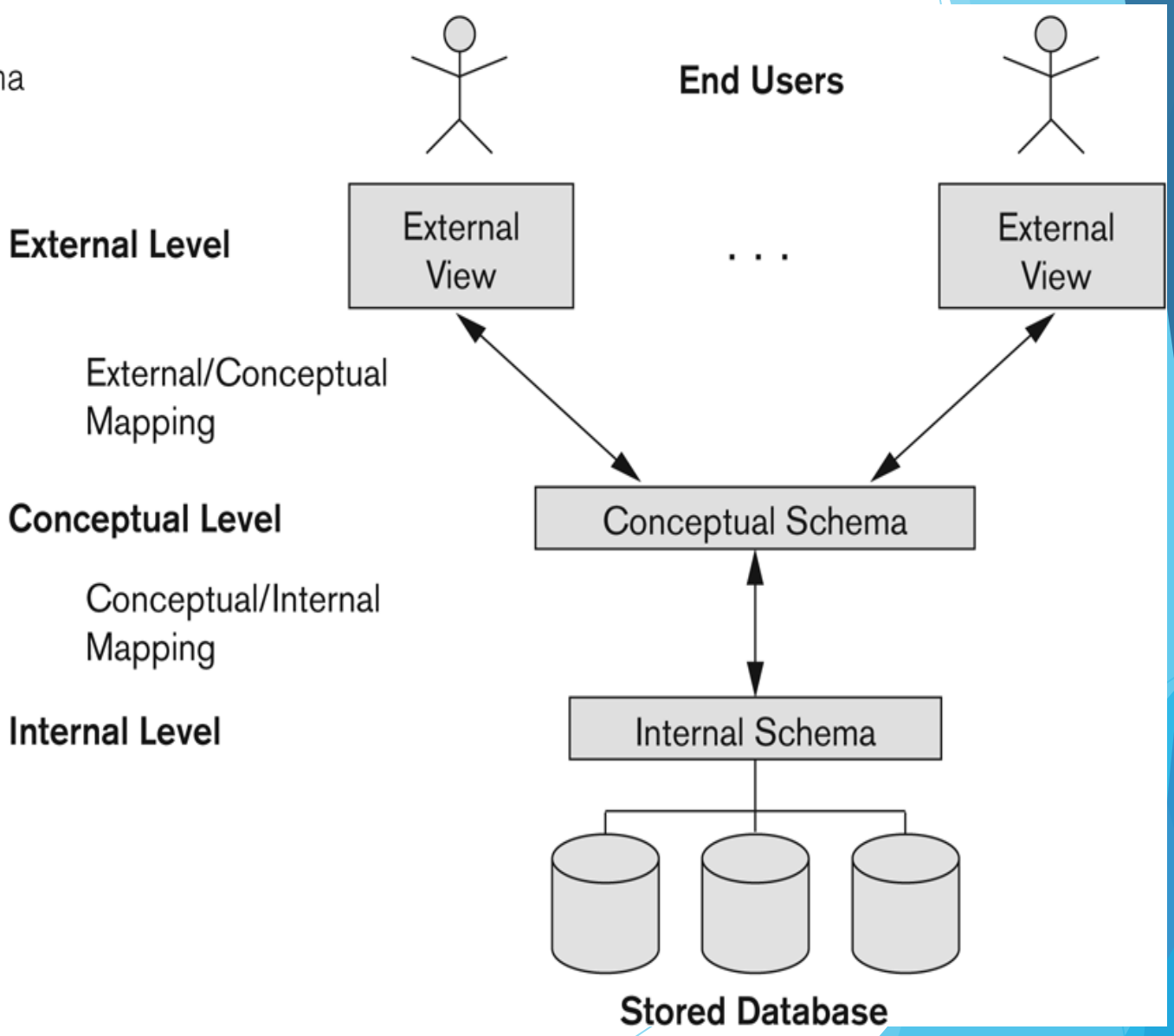
- Proposed to support DBMS characteristics of:
  - **Program-data independence.**
  - Support of **multiple views** of the data.
- Not explicitly used in commercial DBMS products, but has been useful in explaining database system organization

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.

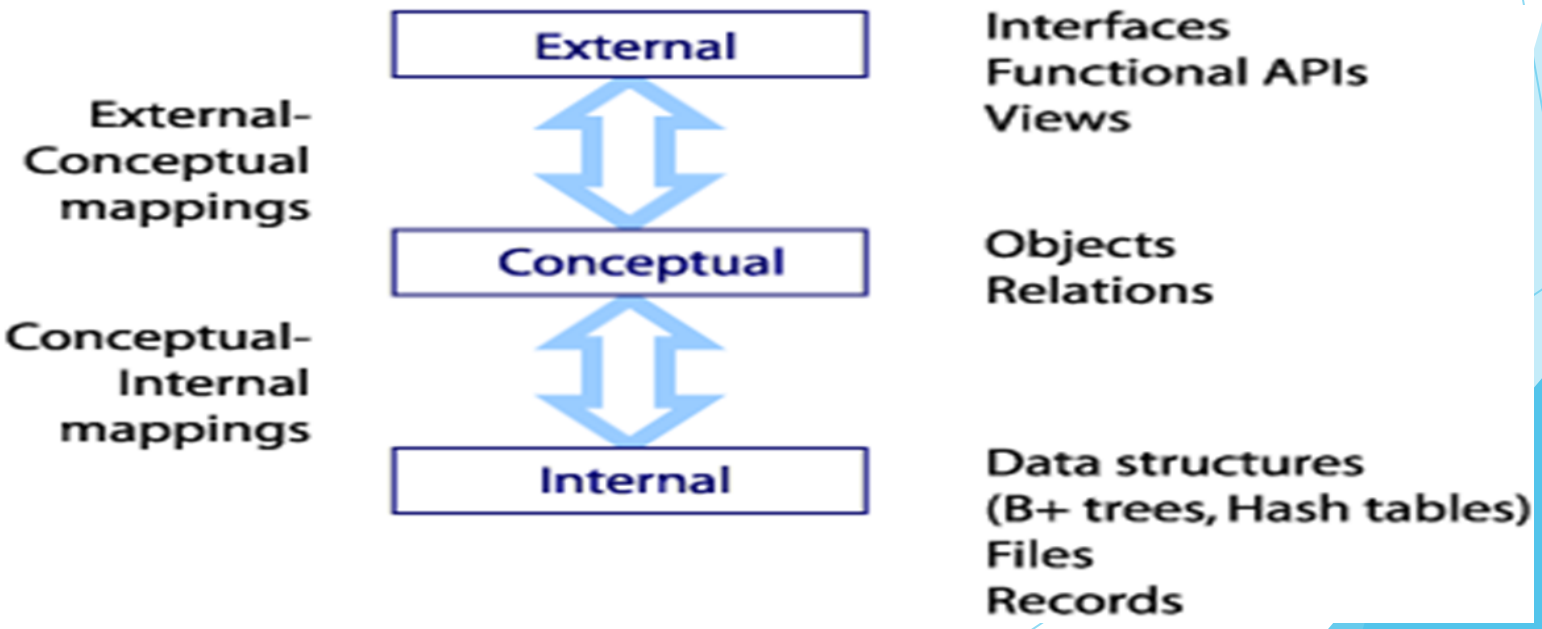
The three-schema architecture

Figure 2.2
The three-schema architecture.



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)



Data Independence

Capacity to change the schema at one level of a database system without having to change the schema at the next higher level.

- **Logical Data Independence**: The capacity to change the conceptual schema without having to change the external schemas and their application programs.

- **Physical Data Independence**: The capacity to change the internal schema without having to change the conceptual schema.

Data Independence

- When a schema at a lower level is changed, only the **mappings** between this schema and higher-level schemas need to be changed in a DBMS that fully supports data independence.
- The higher-level schemas themselves are **unchanged**.
  - Hence, the application programs need not be changed since they refer to the external schemas.

DBMS Languages

- Data Definition Language (DDL)
- Data Manipulation Language (DML)
  - 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 programming language

DBMS Languages

- **Data Definition Language (DDL):**
  - Used by the DBA and database designers to specify the conceptual schema of a database.
  - In many DBMSs, the DDL is also used to define internal and external schemas (views).
  - In some DBMSs, separate **storage definition language (SDL)** and **view definition language (VDL)** are used to define internal and external schemas.
    - SDL is typically realized 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 sublanguage) can be *embedded* in a general-purpose programming language (host language), such as COBOL, 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*).

Types of DML

- **High Level or Non-procedural Language:**
  - For example, the SQL relational language
  - Are “set”-oriented and specify what data to retrieve rather than how to retrieve it.
  - Also called **declarative** languages.
- **Low Level or Procedural Language:**
  - Retrieve data one record-at-a-time;
  - Constructs such as looping are needed to retrieve multiple records, along with positioning pointers.

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, etc.
- Mobile Interfaces:interfaces allowing users to perform transactions using mobile apps

DBMS Programming Language Interfaces

- Programmer interfaces for embedding DML in a programming languages:
  - **Embedded Approach**:
    - e.g embedded SQL (for C, C++, etc.), SQLJ (for Java)
  - **Procedure Call Approach**:
    - e.g. JDBC for Java, ODBC (Open Databse Connectivity) for other programming languages as API's (application programming interfaces)
  - **Database Programming Language Approach**:
    - e.g. ORACLE has PL/SQL, a programming language based on SQL; language incorporates SQL and its data types as integral components
  - **Scripting Languages:**
    - PHP (client-side scripting) and Python (server-side scripting) are used to write database programs.

User-Friendly DBMS Interfaces

- Menu-based (Web-based), popular for browsing on the web
- Forms-based, designed for naïve users used to filling in entries on a form
- Graphics-based
  - Point and Click, Drag and Drop, etc.
  - Specifying a query on a schema diagram
- Natural language: requests in written English
- Combinations of the above:
  - For example, both menus and forms used extensively in Web database interfaces

Other DBMS Interfaces

- Natural language:
  - free text as a query
- Speech :
  - Input query and Output response
- Web Browser with keyword search
- Parametric interfaces,
  - e.g., bank tellers using function keys.
- Interfaces for the DBA:
  - Creating user accounts, granting authorizations
  - Setting system parameters
  - Changing schemas or access paths

Database System Utilities

- To perform certain functions such as:
  - Loading data stored in files into a database. Includes data conversion tools.
  - Backing up the database periodically on tape.
  - Reorganizing database file structures.
  - Performance monitoring utilities.
  - Report generation utilities.
  - Other functions, such as sorting, user monitoring, data compression, etc.

Other Tools

- Data dictionary / repository:
  - Used to store schema descriptions and other information such as design decisions, application program descriptions, user information, usage standards, etc.
- Application Development Environments and CASE (computer-aided software engineering) tools:
  - PowerBuilder (Sybase), JBuilder (Borland), JDeveloper 10G (Oracle)

Typical DBMS Component Modules

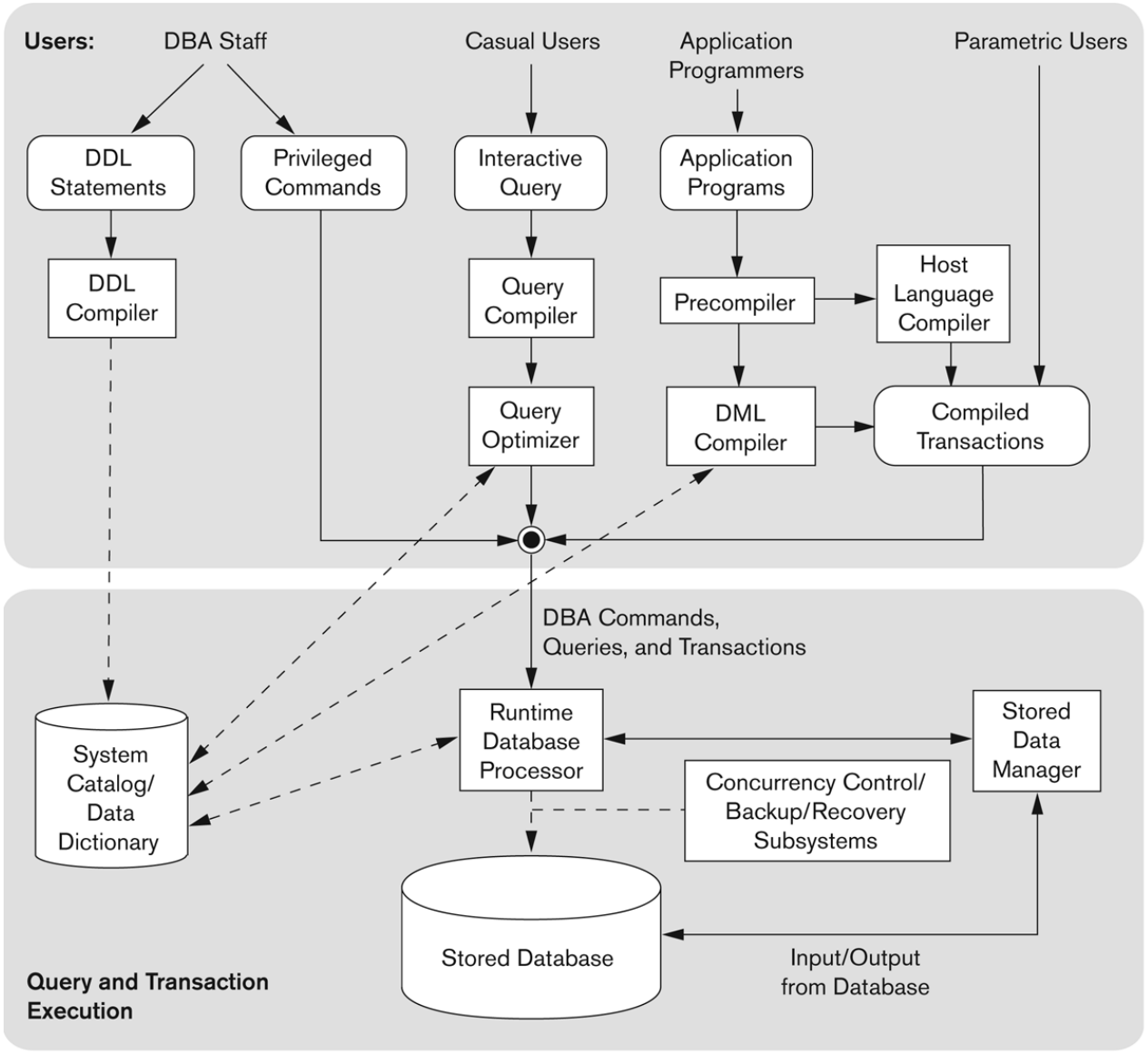


Figure 2.3
Component modules of a DBMS and their interactions.

Centralized and Client-Server DBMS Architectures

- Centralized 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 centralized site.

A Physical Centralized Architecture

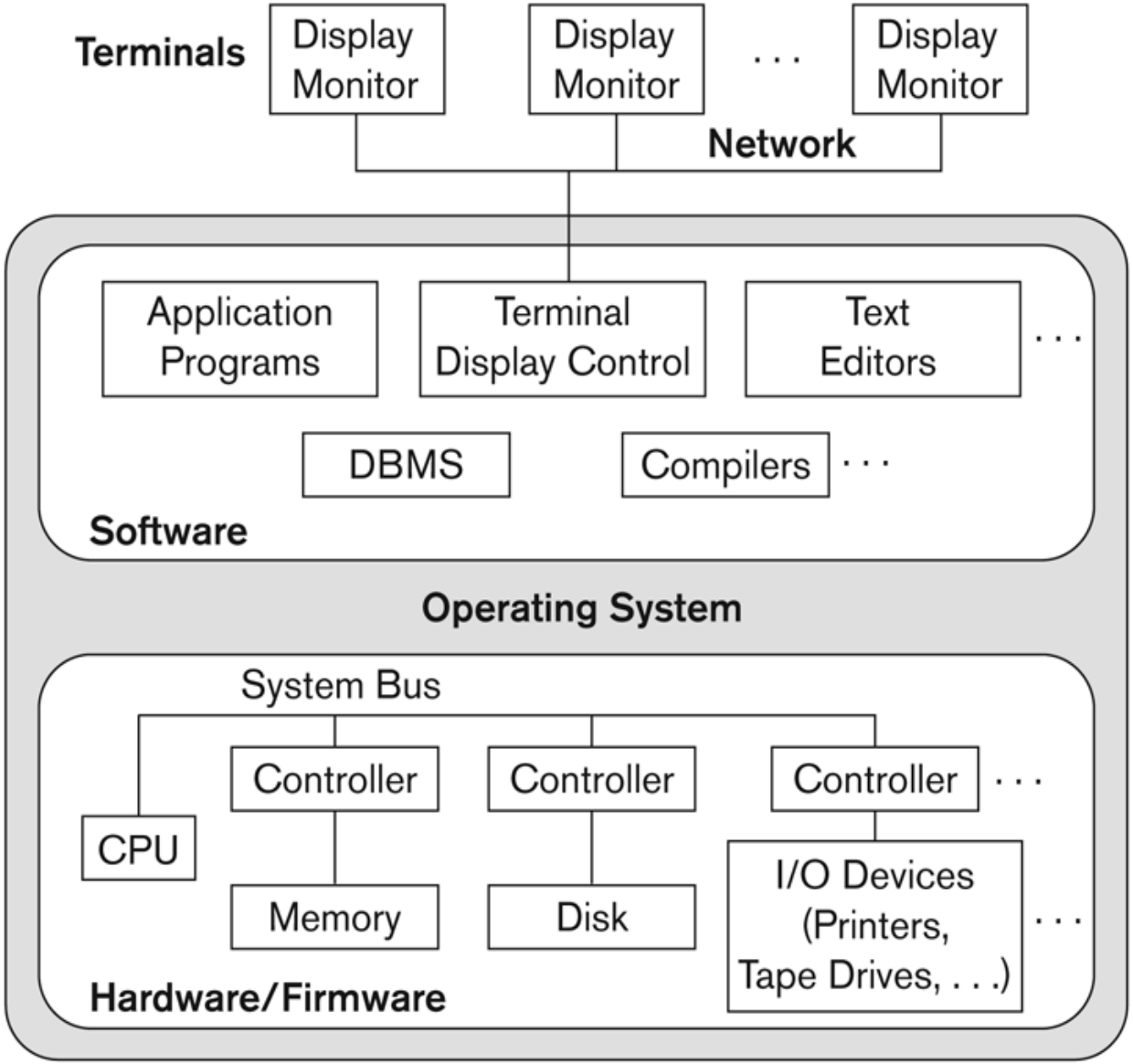
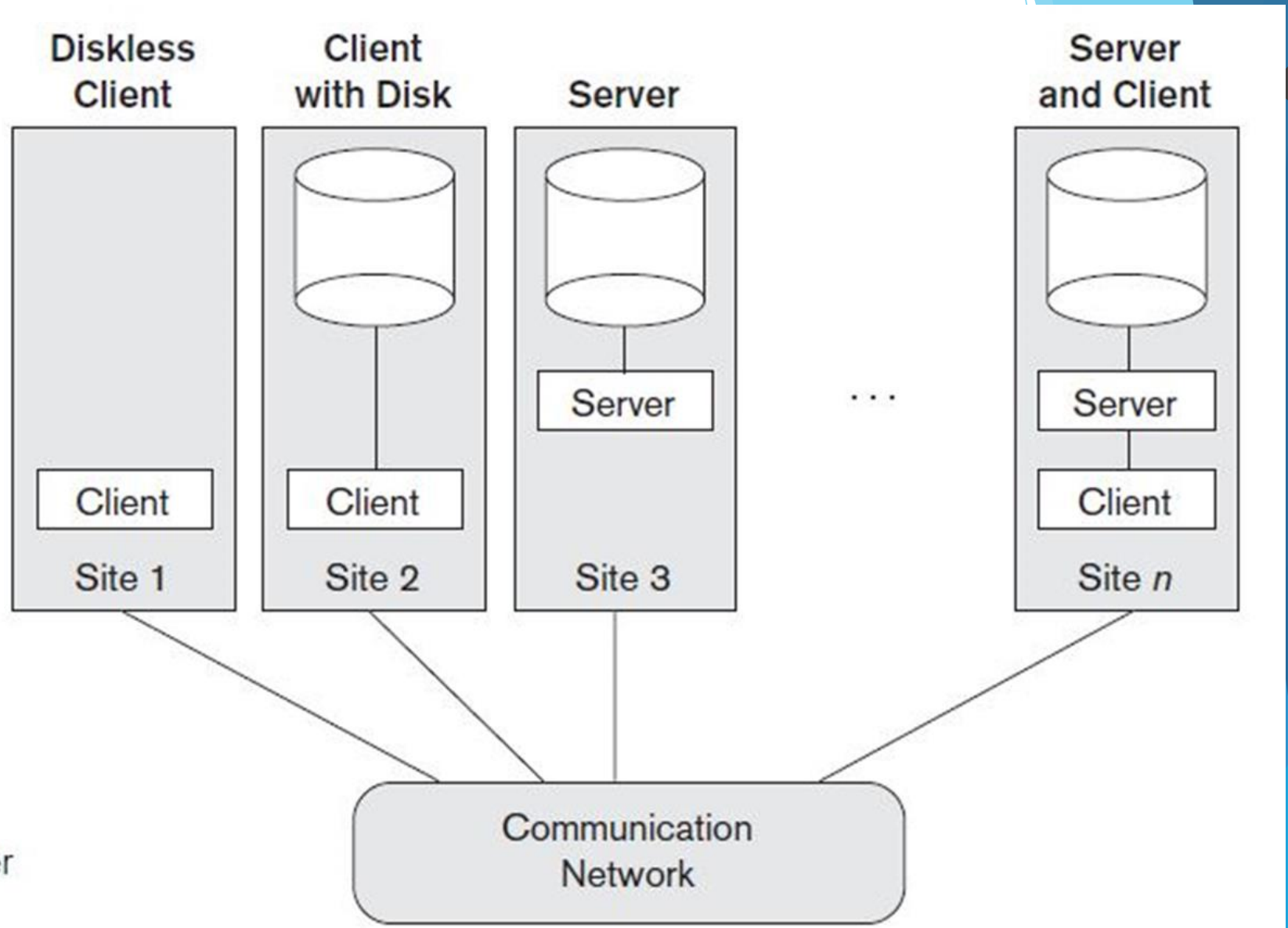


Figure 2.4
A physical centralized architecture.

Basic 2-tier Client-Server Architectures



Clients

- Provide appropriate interfaces through a client software module to access and utilize the various server resources.
- Clients may be diskless machines or PCs or Workstations with disks with only the client software installed.
- Connected to the servers via some form of a network.
  - (LAN: local area network, wireless network, etc.)

DBMS Server

- Provides database query and transaction services to the clients
- Relational DBMS servers are often called SQL servers, query servers, or transaction servers
- Applications running on clients utilize an Application Program Interface (**API**) to access server databases via standard interface such as:
  - ODBC: Open Database Connectivity standard
  - JDBC: for Java programming access

Two Tier Client-Server Architecture

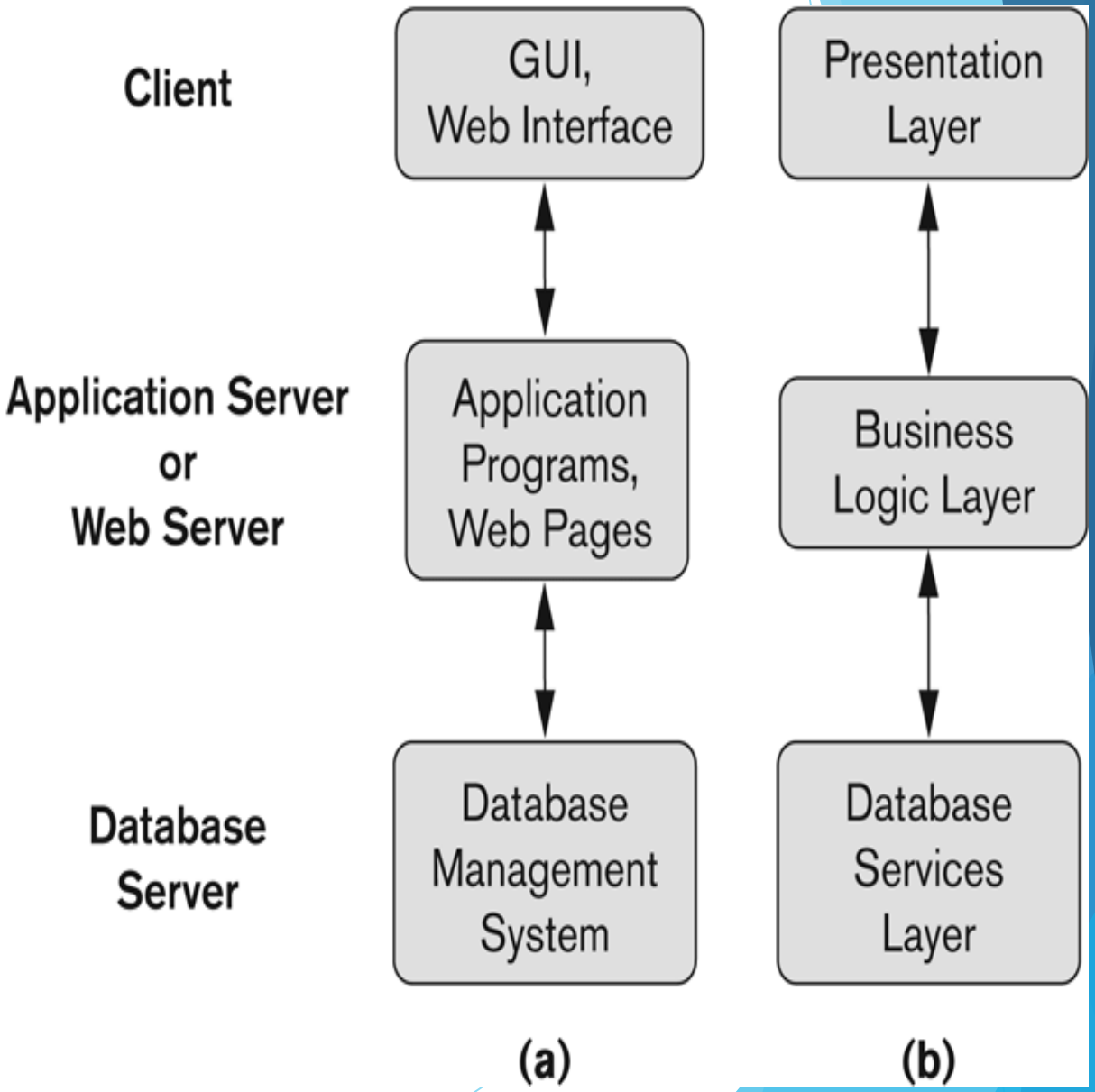
- Client and server must install appropriate client module and server module software for ODBC or JDBC
- A client program may connect to several DBMSs, sometimes called the data sources.
- In general, data sources can be files or other non-DBMS software that manages data.
- See Chapter 10 for details on Database Programming

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
  - Clients contain user interfaces and Web browsers
  - The client is typically a PC or a mobile device connected to the Web

Three-tier client-server architecture

Figure 2.7
Logical three-tier client/server architecture, with a couple of commonly used nomenclatures.



Classification of DBMSs

- Based on the data model used
  - **Legacy**: Network, Hierarchical.
  - **Currently Used**: Relational, Object-oriented, Object-relational
  - **Recent Technologies**: Key-value storage systems, NOSQL systems: document based, column-based, graph-based and key-value based. Native XML DBMSs.
- Other classifications
  - Single-user (typically used with personal computers) vs. multi-user (most DBMSs).
  - Centralized (uses a single computer with one database) vs. distributed (multiple computers, multiple DBs)

Variations of Distributed DBMSs (DDBMSs)

- Homogeneous DDBMS
- Heterogeneous DDBMS
- Federated or Multidatabase Systems
  - Participating Databases are loosely coupled with high degree of autonomy.
- Distributed Database Systems have now come to be known as client-server based database systems because:
  - They do not support a totally distributed environment, but rather a set of database servers supporting a set of clients.

Cost considerations for DBMSs

- Cost Range: from free open-source systems to configurations costing millions of dollars
- Examples of free relational DBMSs: MySQL, PostgreSQL, others
- Commercial DBMS offer additional specialized modules, e.g. time-series module, spatial data module, document module, XML module
  - These offer additional specialized functionality when purchased separately
  - Sometimes called cartridges (e.g., in Oracle) or blades
- Different licensing options: site license, maximum number of concurrent users (seat license), single user, etc.

Other Considerations

- Type of access paths within database system
  - E.g.- inverted indexing based (ADABAS is one such system).Fully indexed databases provide access by any keyword (used in search engines)
- General Purpose vs. Special Purpose
  - E.g.- Airline Reservation systems or many others- reservation systems for hotel/car etc. Are special purpose OLTP (Online Transaction Processing Systems)

History of Data Models

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

History of Data Models

- **Relational Model:**
  - Proposed in 1970 by E.F. Codd (IBM), first commercial system in 1981-82.
  - Now 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.
  - SQL relational standards: SQL-89 (SQL1), SQL-92 (SQL2), SQL-99, SQL3, …
  - Chapters 5 through 11 describe this model in detail

History of Data Models

- **Object-oriented Data Models:**
  - Several models have been proposed for implementing in a database system.
  - One set comprises models of persistent O-O Programming Languages such as C++ (e.g., in OBJECTSTORE or VERSANT), and Smalltalk (e.g., in GEMSTONE).
  - Additionally, systems like O2, ORION (at MCC - then ITASCA), IRIS (at H.P.- used in Open OODB).
  - Object Database Standard: ODMG-93, ODMG-version 2.0, ODMG-version 3.0.
  - Chapter 12 describes this model.

History of Data Models

- **Object-Relational Models:**
  - The trend to mix object models with relational was started with Informix Universal Server.
  - Relational systems incorporated concepts from object databases leading to object-relational.
  - Exemplified in the versions of Oracle, DB2, and SQL Server and other DBMSs.
  - Current trend by Relational DBMS vendors is to extend relational DBMSs with capability to process XML, Text and other data types.
  - The term “Object-relational” is receding in the marketplace.

Summary

- We defined a data model and we distinguished three main categories
- We distinguished the schema, Then we described the three-schema DBMS architecture, which allows three schema levels
- We discussed the main types of languages and interfaces that DBMSs support
- We discussed different types of interfaces provided by DBMSs
- we classified DBMSs according to several criteria

Refferance

- Chapter 2 : *Fundamentals of Database Systems*

(6th Edition) By Remez Elmasri & Shamkant B. Navathe

Questions ???

Thank You