Course Contents

Unit-02: Database System – Concepts and Architecture

- Data Models, Schemas, and Instances;
- Three-Schema Architecture and Data Independence;
- Database Languages and Interfaces;
- Database System Environment;
- Centralized and Client/Server Architectures for DBMSs;
- Classification of Database Management Systems

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Database System Concepts and Architecture:

The evolution computing trends replaced large centralized mainframe computers by hundreds of distributed workstations and personal computers connected via communications networks to various types of server machines—Web servers, database servers, file servers, application servers, and so on.

The current cloud computing environments consist of thousands of large servers managing so-called big data for users on the Web.

In a basic client/server DBMS architecture, the **system functionality** is distributed between two types of modules- Client Module and Server Module.

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Database System Concepts and Architecture:

A client module is designed to run on a mobile device, user workstation, or personal computer (PC). Application programs and user interfaces that access the database run in the client module. Hence, the client module handles user interaction and provides the user-friendly interfaces such as apps for mobile devices, or forms- or menu based GUIs (graphical user interfaces) for PCs.

Where as a server module, handles data storage, access, search, and other functions.

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Database System Concepts and Architecture:

We will learn about Centralized and Client/Server Architectures for DBMSs.

But before to learn about Centralized and Client/Server Architectures,

We learn the terminology and basic concepts about Data Model and concept of schemas and instances that will be used throughout the course, which are fundamental to the study of database systems.

We further discuss the three-schema DBMS architecture and data independence and provides a user's perspective on what a DBMS is supposed to do. We learn the types of interfaces and languages that are provided by a DBMS and about the database system software environment.

Finally, a classification of the types of DBMS packages.

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Database System Concepts and Architecture:

We learn about:

- Data model
- Schemas and instances
- Three-schema DBMS architecture
- Data independence
- Types of interfaces and languages that are provided by a DBMS
- Database system software environment.
- Types of DBMS packages.

Course Contents

Data Models, Schemas, and Instances:

Data models are a collection of conceptual tools for describing **data**, **data relationships**, **data semantics** and **data constraints**. It is a graphical representation of data.

Data models are groups are as:

1. Entity-Relationship Model
2. Hierarchical
3. Network Models
4. Relational Model

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Database Models?

E-R Diagram:

- The entity-relationship model is based on a perception of the world as consisting of a collection of basic objects (entities) and relationships among these objects.

- An entity is a distinguishable objects that exists and we want to keep the information about. Each entity has associated with it a set of attributes describing it.

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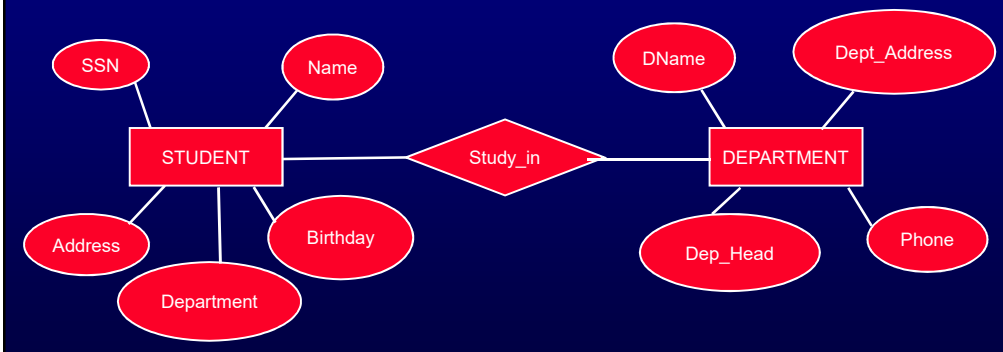
Database Models?

E-R Diagram:



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Database Models?

Relational Model:

- Data and relationships are represented by a collection of tables.
- Each table has a number of columns with unique names, e.g. STUDENT, DEPARTMENT

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Database Models?

Relational Model:

STUDENT

SSN	Name	Address	Department	Birthday
001	Shankar	Kathmandu	Computer Sc.	04/01/2031
002	Hari	Lalitpur	Computer Sc.	04/02/2032
003	Shyam	Lalitpur	Physics	04/03/2033
004	Ram	Kathmandu	Physics	05/12/2034
005	Deepak	Kirtipur	Chemistry	06/11/2035

DEPARTMENT

DName	Dept_Address	Dep_Head	Phone
Computer Sc.	Lalitpur	AAA	4444444
Physics	Lalitpur	BBB	5555555
Chemistry	Lalitpur	CCC	6666666

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Database Models?

Network Model:

- Data are represented by collections of records.
- Relationships among data are represented by links.
- Organization is that of an **arbitrary graph**

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Database Models?

Network Model:

Course Contents

Database Models?

Hierarchical Model:

- Similar to the network model.
- Organization of the records is as a collection of trees, rather than arbitrary graphs.

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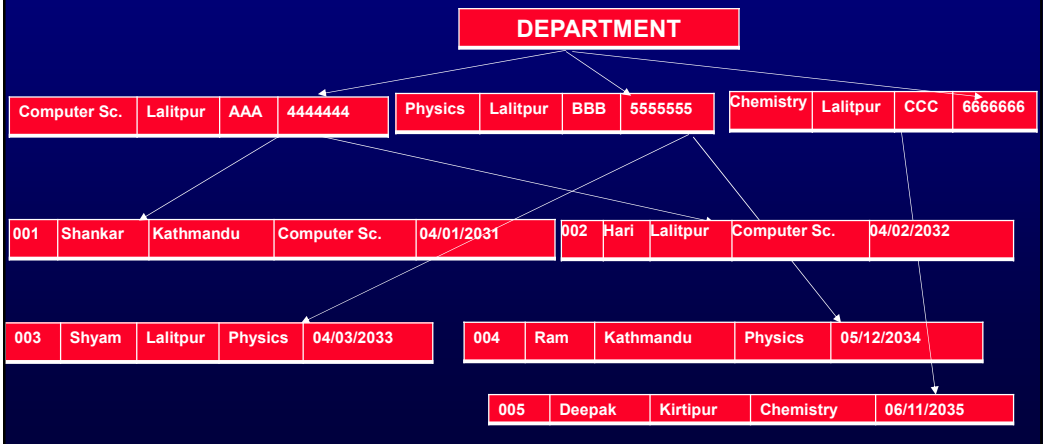
Database Models?

Hierarchical Model:



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Data Models:

Database approach provides some level of data abstraction. Data abstraction generally refers to the suppression of details of data organization and storage, and the highlighting of the essential features for an improved understanding of data. One of the main characteristics of the database approach is to support data abstraction so that different users can perceive data at their preferred level of detail.

A data model - a collection of concepts that can be used to describe the structure of a database - provides the necessary means to achieve this abstraction.

By structure of a database mean the data types, relationships, and constraints that apply to the data. Most data models also include a set of basic operations for specifying retrievals and updates on the database.

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Data Models:

In addition to the basic operations provided by the data model, it is becoming more common to include concepts in the data model to specify the dynamic aspect or behavior of a database application.

This allows the database designer to specify a set of valid user-defined operations that are allowed on the database objects.

An example of a user-defined operation could be COMPUTE_GPA, which can be applied to a STUDENT object. On the other hand, generic operations to insert, delete, modify, or retrieve any kind of object are often included in the basic data model operations.

Concepts to specify behavior are fundamental to object-oriented data models but are also being incorporated in more traditional data models.

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Categories of Data Models:

Many data models have been proposed, which we can categorize according to the types of concepts they use to describe the database structure.

High-level or conceptual data models provide concepts that are close to the way many users perceive data, whereas low-level or physical data models provide concepts that describe the details of how data is stored on the computer storage media, typically magnetic disks.

Concepts provided by physical data models are generally meant for computer specialists, not for end users. Between these two extremes is a class of representational (or implementation) data models, which provide concepts that may be easily understood by end users but that are not too far removed from the way data is organized in computer storage. Representational data models hide many details of data storage on disk but can be implemented on a computer system directly.

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Categories of Data Models:

1. High-level or conceptual data models: Entity–Relationship model- a popular high-level conceptual data model.

2. Representational (or implementation) data models: most frequently use in traditional commercial DBMSs. These include the widely used relational data model, as well as the so-called legacy data models-the network and hierarchical models - that have been widely used in the past. Representational data models represent data by using record structures and hence are sometimes called record-based data models.

3. Object data model: an example of a new family of higher-level implementation data models that are closer to conceptual data models. A standard for object databases called the ODMG object model has been proposed by the Object Data Management Group (ODMG).

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Categories of Data Models:

4. Physical data models: describe how data is stored as files in the computer by representing information such as record formats, record orderings, and access paths. An access path is a search structure that makes the search for particular database records efficient, such as indexing or hashing.

5. Self-describing data models: The data storage in systems based on these models combines the description of the data with the data values themselves. In traditional DBMSs, the description (schema) is separated from the data. These models include XML (eXtensible Markup Language) as well as many of the key-value stores and NOSQL systems that were recently created for managing big data.

Schemas and Instances

- The current contents of a database, we term an instance of the database.
- When the database is designed, we are interested in plans(Schema) for the database. But when it is used, we are concerned with the actual data present in the database. The data in a database changes frequently, while the plans remain the same over long period of time.
- So Schema is a plan where data(instances) are changing.

Schemas and Instances

Example:

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.

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.

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Schemas, Instances, and Database State:

In a data model, it is important to distinguish between the description of the database and the database itself.

Database Schema - The description of a database is called the database schema, which is specified during database design and is not expected to change frequently. Most data models have certain conventions for displaying schemas as diagrams. A displayed schema is called a schema diagram. The diagram displays the structure of each record type but not the actual instances of records.

Schema Diagram for database:

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

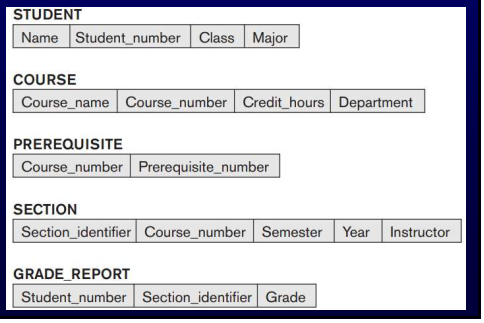
We call each object in the schema- such as STUDENT or COURSE - a schema construct.

Course Contents

Schemas, Instances, and Database State:

A schema diagram displays only some aspects of a schema, such as the names of record types and data items, and some types of constraints. Other aspects like data type of each data item, the relationships among the various files are not specified in the schema diagram. Many types of constraints are not represented in schema diagrams.

Schema Diagram for database:



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Schemas, Instances, and Database State:

Instances (Database State) - The data in the database at a particular moment in time is called a database state or snapshot. It is also called the current set of occurrences or instances in the database.

The actual data in a database may change quite frequently. For example, the database shown in Figure changes every time we add a new student or enter a new grade.

Although, the schema is not supposed to change frequently, but changes occasionally need to be applied to the schema as the application requirements change. For example, we may decide that another data item needs to be stored for each record in a file, such as adding the Date_of_birth to the STUDENT schema. This is known as schema evolution. Most modern DBMSs include some operations for schema evolution that can be applied while the database is operational.

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Schemas, Instances, and Database State:

Database schema Vs Database State - The distinction between database schema and database state is very important. When we define a new database, we specify its database schema only to the DBMS. At this point, the corresponding database state is the empty state with no data. We get the initial state of the database when the database is first inserted with the initial data. From then on, every time an update operation is applied to the database, we get another database state. At any point in time, the database has a current state. The DBMS is partly responsible for ensuring that every state of the database is a valid state—that is, a state that satisfies the structure and constraints specified in the schema. Hence, specifying a correct schema to the DBMS is extremely important and the schema must be designed with utmost care. The DBMS stores the descriptions of the schema constructs and constraints—also called the meta-data - in the DBMS catalog so that DBMS software can refer to the schema whenever it needs to. The schema is sometimes called the **intension**, and a database state is called an **extension** of the schema.

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Three-Schema Architecture and Data Independence:

Data Abstraction

Three-Schema Architecture

What is Abstraction?

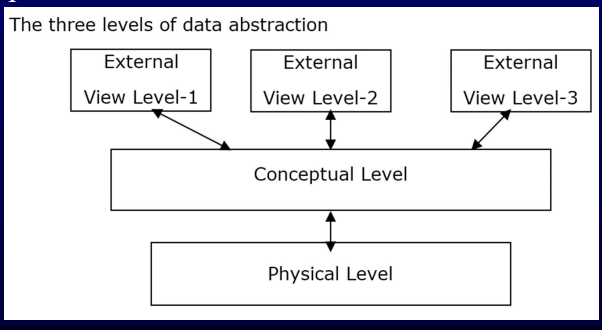
- Abstraction, in general, is the process of taking away or removing characteristics from something in order to reduce it to a set of essential characteristics.
- The major purpose of a database system is to provide users with an abstract view of the system. The system hides certain details of how data is stored and created and maintained.
- Complexity should be hidden from database users.

So, abstraction refers to the act of representing essential features without including the background details or explanations.

Data Abstraction

There are 3 levels of abstraction.

The levels form a three-level architecture that includes an external, a conceptual, and an internal(physical) level. The way users recognize the data is called the external level. The way the DBMS and the operating system distinguish the data is the internal level, where the data is stored using the data structures and file. The conceptual level offers both the mapping and the desired independence between the external and internal levels.



Data Abstraction

There are 3 levels of abstraction.

1. Physical Level:

- How the data are stored (e.g. index, B-tree, hashing.
- Lowest level of abstraction.
- Complex low-level structures described in detail.

2. Conceptual Level:

- Next highest level of abstraction.
- Describes what data are stored.
- Describes the relationships among data.
- Database administrator level.

Data Abstraction

There are 3 levels of abstraction.

3. View Level:

- Highest level.
- Describes part of the database for a particular group of users.
- Can be many different views of a database.

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Three-Schema Architecture and Data Independence:

Four important characteristics of the Three-Schema Architecture database approach:

1. Self-describing nature of a database system - use of a catalog to store the database description (schema) so as to make it self-describing
2. Insulation between programs and data, and data abstraction - program-data and program-operation independence
3. Support of multiple views of the data
4. Sharing of data and multiuser transaction processing

An architecture for database systems, called the three-schema architecture, to help achieve and visualize these characteristics.

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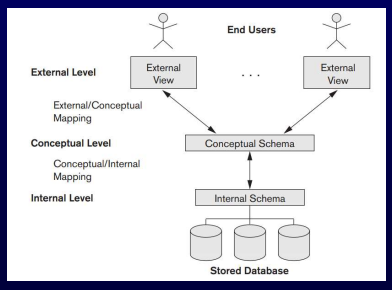
Goal of the three-schema architecture



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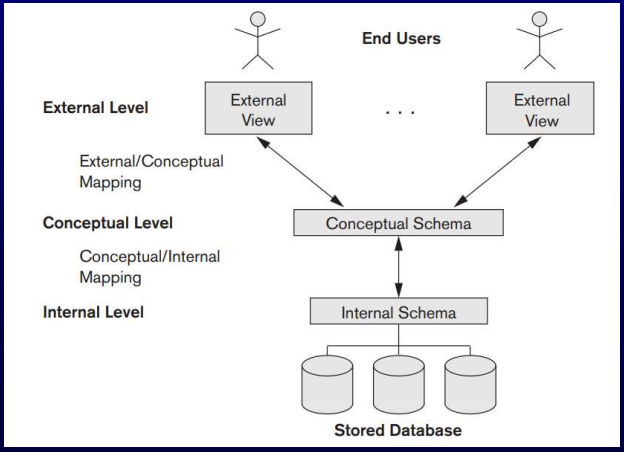
The Three-Schema Architecture:

The goal of the three-schema architecture is to separate the user applications from the physical database. In this architecture, schemas can be defined at the following three levels:



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The Three-Schema Architecture:

The goal of the three-schema architecture is to separate the user applications from the physical database. In this architecture, schemas can be defined at the following three levels:

1. The internal level has an internal schema, which describes the physical storage structure of the database. The internal schema uses a physical data model and describes the complete details of data storage and access paths for the database.
2. The conceptual level has a conceptual schema, which describes the structure of the whole database for a community of users. The conceptual schema hides the details of physical storage structures and concentrates on describing entities, data types, relationships, user operations, and constraints. Usually, a representational data model is used to describe the conceptual schema. This implementation conceptual schema is often based on a conceptual schema design in a high-level data model.

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The Three-Schema Architecture:

3. The external or view level includes a number of external schemas or user views. Each external schema describes the part of the database that a particular user group is interested in and hides the rest of the database from that user group. As in the previous level, each external schema is typically implemented using a representational data model, possibly based on an external schema design in a high-level conceptual data model.

The three-schema architecture is a convenient tool with which the user can visualize the schema levels in a database system.

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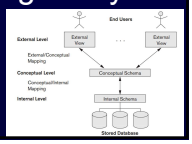
The Three-Schema Architecture:

What is Mapping in 3-level architecture?

Notice that the three schemas are only descriptions of data while the actual data is stored at the physical level only.

In the three-schema architecture, each user group refers to its own external schema. Hence, the DBMS must transform a request specified on an external schema into a request against the conceptual schema, and then into a request on the internal schema for processing over the stored database. If the request is a database retrieval, the data extracted from the stored database must be reformatted to match the user's external view. The processes of transforming requests and results between levels are called mappings. These mappings may be time-consuming.



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Data Independence:

The three-schema architecture can be used to further explain the concept of data independence, which can be defined as the capacity to change the schema at one level of a database system without having to change the schema at the next higher level.

We can define two types of data independence:

1. Logical data independence is the capacity to change the conceptual schema without having to change external schemas or application programs. We may change the conceptual schema to expand the database (by adding a record type or data item), to change constraints, or to reduce the database (by removing a record type or data item).

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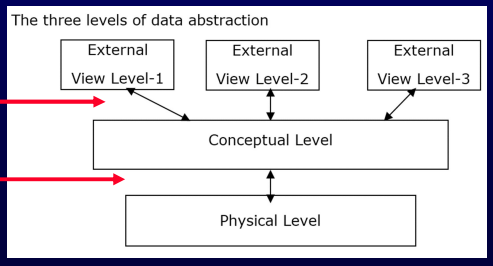
Data Independence:

External schemas that refer only to the remaining data should not be affected. Only the view definition and the mappings need to be changed in a DBMS that supports logical data independence. After the conceptual schema undergoes a logical reorganization, application programs that reference the external schema constructs must work as before. Changes to constraints can be applied to the conceptual schema without affecting the external schemas or application programs.

Logical Data Independence

Physical Data Independence



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Data Independence:

2. Physical data independence: is the capacity to change the internal schema without having to change the conceptual schema. Hence, the external schemas need not be changed as well. Changes to the internal schema may be needed because some physical files were reorganized.

   For example, by creating additional access structures to improve the performance of retrieval or update. If the same data as before remains in the database, we should not have to change the conceptual schema.

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Data Independence:

Generally, physical data independence exists in most databases and file environments where physical details, such as the exact location of data on disk, and hardware details of storage encoding, placement, compression, splitting, merging of records, and so on are hidden from the user. Applications remain unaware of these details.

On the other hand, logical data independence is harder to achieve because it allows structural and constraint changes without affecting application programs—a much stricter requirement.

Database Languages

Database Languages are mainly of two types:

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

DDL can also be defined as

- SDL (Storage Definition Language)
- VDL (View Definition Language)

Database Languages

DDL (Data Definition Language):

- In ordinary high level Language, both Declaration and Executable statements are all part of one language.
- In DBMS, Declaration and Executables(Computation) into two different languages i.e. DDL and DML
- DDL Language is used to specify a database scheme as a set of definitions.
- DDL is not a procedural language. It is for describing the types of entities and relationships among entities.
- It is not used for obtaining or modify the data itself.

Database Languages

DML (Data Manipulation Language):

- A DML is a language which enables users to access and manipulate data.
- DML is for retrieval, insertion, deletion and modification of information from or in the database

There are two types of DML:

Procedural: the user specifies what data is needed and how to get it. E.g. SQL

Nonprocedural: the user only specifies what data is needed (E.g. QBE)

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Database Languages and Interfaces:

- We discussed the variety of users supported by a DBMS.
- The DBMS must provide appropriate languages and interfaces for each category of users.
- We learn the types of languages and interfaces provided by a DBMS and the user categories targeted by each interface.

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DBMS Languages:

Once the design of a database is completed and a DBMS is chosen to implement the database, the first step is to specify conceptual and internal schemas for the database and any mappings between the two.

One language, called the data definition language (DDL), is used by the DBA and by database designers to define both schemas. The DBMS will have a DDL compiler whose function is to process DDL statements in order to identify descriptions of the schema constructs and to store the schema description in the DBMS catalog.

In DBMSs where a clear separation is maintained between the conceptual and internal levels, the DDL is used to specify the conceptual schema only. Another language, the storage definition language (SDL), is used to specify the internal schema. The mappings between the two schemas may be specified in either one of these languages.

In most relational DBMSs today, there is no specific language that performs the role of SDL.

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DBMS Languages:

We would need a third language, the view definition language (VDL), to specify user views and their mappings to the conceptual schema, but in most DBMSs the DDL is used to define both conceptual and external schemas. In relational DBMSs, SQL is used in the role of VDL to define user or application views as results of predefined queries.

Once the database schemas are compiled and the database is populated with data, users must have some means to manipulate the database. Typical manipulations include retrieval, insertion, deletion, and modification of the data. The DBMS provides a set of operations or a language called the data manipulation language (DML) for these purposes.

Database Concepts and Architecture

The Database System Environment:

A DBMS is a complex software system. We discuss the types of software components that constitute a DBMS and the types of computer system software with which the DBMS interacts.

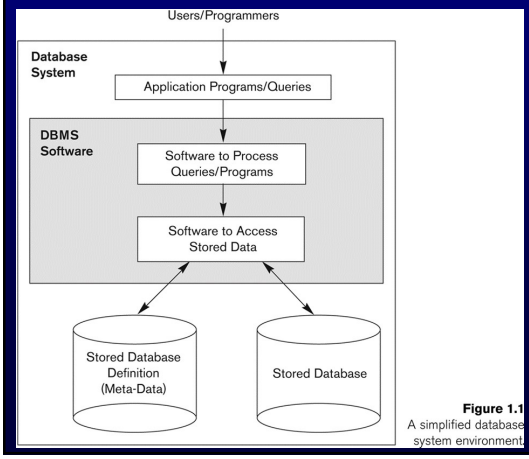


Figure 1.1
A simplified database system environment.

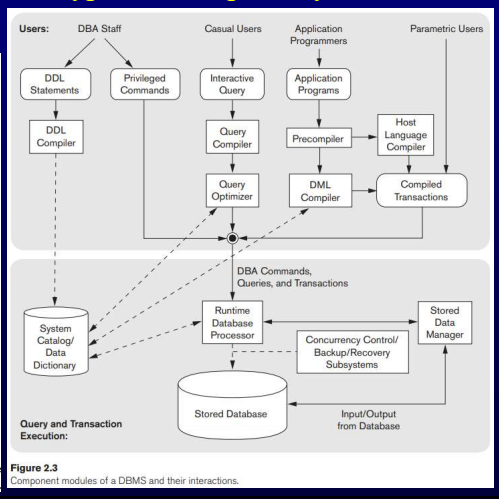


Figure 2.3
Component modules of a DBMS and their interactions.

Database Concepts and Architecture

DBMS Component Modules:

A simplified form of DBMS components. The figure is divided into two parts.

- The top part of the figure refers to the various users of the database environment and their interfaces.
- The lower part shows the internal modules of the DBMS responsible for storage of data and processing of transactions.

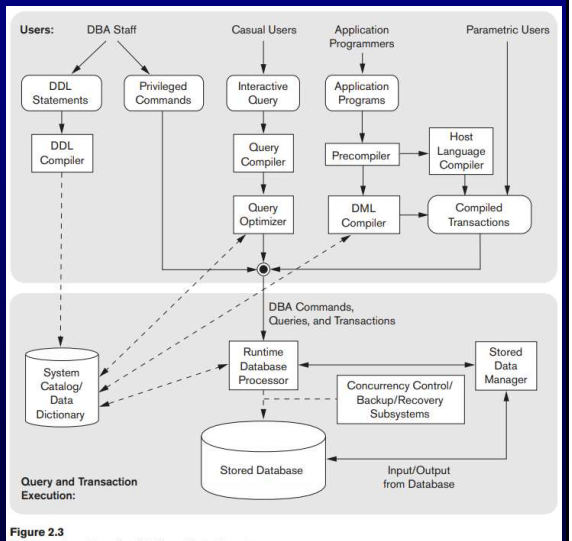


Figure 2.3
Component modules of a DBMS and their interactions.

Database Concepts and Architecture

DBMS Component Modules:

Stored Data Manager: The database and the DBMS catalog are usually stored on disk. A higher-level stored data manager module of the DBMS controls access to DBMS information that is stored on disk, whether it is part of the database or the catalog. Access to the disk is controlled primarily by the operating system (OS), which schedules disk read/write. Many DBMSs have their own buffer management module to schedule disk read/write, because management of buffer storage has a considerable effect on performance. Reducing disk read/write improves performance considerably.

- Various types of database users are shown on top of figure. Each users have their own jobs and functions and interfaces with different components of Database system.
- The DBA staff works on defining the database and tuning it by making changes to its definition using the DDL and other privileged commands. The DDL compiler processes schema definitions, specified in the DDL, and stores descriptions of the schemas (meta-data) in the DBMS catalog (System Catlogue /Data Dictionary). The catalog includes information such as the names and sizes of files, names and data types of data items, storage details of each file, mapping information among schemas, and constraints.

Database Concepts and Architecture

DBMS Component Modules:

Casual users and persons: who occasionally need for information from the database interact using the interactive query interface. Intercative queries are in the form of menu-based or form-based or mobile interactions that are typically used to generate the interactive query automatically or to access transactions. These queries are parsed and validated for correctness of the query syntax, the names of files and data elements, and so on by a query compiler that compiles them into an internal form.

This internal query is passed through the query optimizer which rearrangement and possible reordering of operations, elimination of redundancies, and use of efficient search algorithms during execution. It consults the system catalog for statistical and other physical information about the stored data and generates executable code that performs the necessary operations for the query and makes calls on the runtime processor.

Database Concepts and Architecture

DBMS Component Modules:

Application programmers write programs in host languages such as Java, C, or C++ and are submitted to a precompiler. The precompiler extracts DML commands from an application program written in a host programming language. These commands are sent to the DML compiler for compilation into object code for database access. The rest of the program is sent to the host language compiler. The object codes for the DML commands and the rest of the program are linked, forming a canned transaction whose executable code includes calls to the runtime database processor.

Canned transactions are executed repeatedly by parametric users via PCs or mobile apps; these users simply supply the parameters to the transactions.

Database Concepts and Architecture

DBMS Component Modules:

Runtime Database Processor : The lower part of Figure, the runtime database processor executes (1) the privileged commands, (2) the executable query plans, and (3) the canned(prerecorded) transactions with runtime parameters. It works with the system catalog and may update it with statistics. It also works with the stored data manager, which in turn uses basic operating system services for carrying out low-level input/output (read/write) operations between the disk and main memory. The runtime database processor handles other aspects of data transfer, such as management of buffers in the main memory. Some DBMSs have their own buffer management module whereas others depend on the OS for buffer management.

The concurrency control and backup and recovery systems separately as a module in the figure. They are integrated into the working of the runtime database processor for purposes of transaction management.

Course Contents

Database System Utilities:

DBMSs have many software modules for possessing as described in Database System Environment. There are database utilities also in DBMS that help the DBA to manage the database system. Common utilities have the following types of functions:

1. Loading: A loading utility is used to load existing data files (text files or others) into the database. Usually, the current (source) format of the data file and the desired (target) database file structure are specified to the utility, which then automatically reformats the data and stores it in the database. Transferring data from one DBMS to another is becoming common in many organizations. Some vendors offer conversion tools that generate the appropriate loading programs, given the existing source and target database storage descriptions (internal schemas).

2. Backup: A backup utility creates a backup copy of the database, usually by dumping the entire database onto tape or other mass storage medium. The backup copy can be used to restore the database in case of catastrophic disk failure. Incremental backups are also often used, where only changes since the previous backup are recorded. Incremental backup is more complex, but saves storage space.

Course Contents

Database System Utilities:

3. Database storage reorganization: This utility can be used to reorganize a set of database files into different file organizations and create new access paths to improve performance.

4. Performance monitoring: This utility monitors database usage and provides statistics to the DBA. The DBA uses the statistics in making decisions such as whether or not to reorganize files or whether to add or drop indexes to improve performance

Other utilities may be available for sorting files, handling data compression, monitoring access by users, interfacing with the network, and performing other functions.

Course Contents

Tools, Application Environments, and Communications Facilities:
Other tools are often available to database designers, users, and the DBMS.

1. CASE tools are used in the design phase of database systems.

2. Expanded Data dictionary (or data repository) system: In addition to storing catalog information about schemas and constraints, the data dictionary stores other information, such as design decisions, usage standards, application program descriptions, and user information. Such a system is also called an information repository. This information can be accessed directly by users or the DBA when needed. A data dictionary utility is similar to the DBMS catalog, but it includes a wider variety of information and is accessed mainly by users rather than by the DBMS software.

3. Application development environments: These systems provide an environment for developing database applications and include facilities that help in many facets of database systems, including database design, GUI development, querying and updating, and application program development i.e. PowerBuilder (Sybase) or Jbuilder.

Course Contents

Tools, Application Environments, and Communications Facilities:

4. Database Communication Interfaces: Different users may access the database through a network environment. So the DBMS provide communication functions to access the database through computer network environment. The integrated DBMS and data communications system is called a DB/DC system. In addition, some distributed DBMSs are physically distributed over multiple machines. In this case, communications networks are needed to connect the machines.

Centralized and Client/Server Architectures for DBMSs:

Three generic database architectures or types of database are:

1. Centralized DBMSs Architecture
2. Client/Server architecture Databases
   - Basic Client/Server Architectures
   - Two-Tier Client/Server Architectures for DBMSs
   - Three-Tier and n-Tier Architectures for Web Applications
3. Distributed Database
   - Homogeneous Databases
   - Heterogeneous Databases

All software systems can be divided into four basic functions.

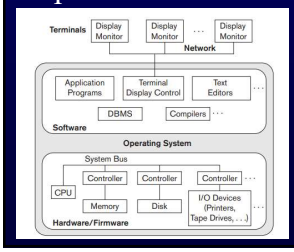
1. Data Storage
2. Data Access Logic (associated with the data access)
3. Application Logic
4. Presentation Logic (located on the human–computer interaction layer)

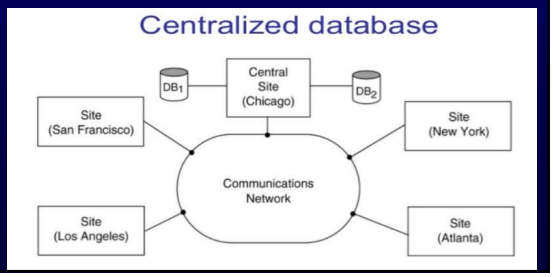
Centralized and Client/Server Architectures for DBMSs;

Centralized DBMSs Architecture

A centralized database is stored at a single location such as a mainframe computer. It is maintained and modified from that location only and usually accessed using an internet connection such as a LAN or WAN.

Older architectures used mainframe computers to provide the main processing for all system functions, including user application programs and user interface programs, as well as all the DBMS functionality. The reason was that in older systems, most users accessed the DBMS via computer terminals that did not have processing power and only provided display capabilities.



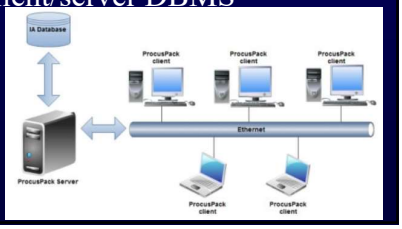


Centralized and Client/Server Architectures for DBMSs;

Client/Server architecture Databases: The client/server databases are used in small to medium organization or businesses to share data among multiple users in local area network. The microcomputers are often used in a local area network.

The client/server architecture is designed for the distribution of work on a computer network in which many clients may share the data (or services).

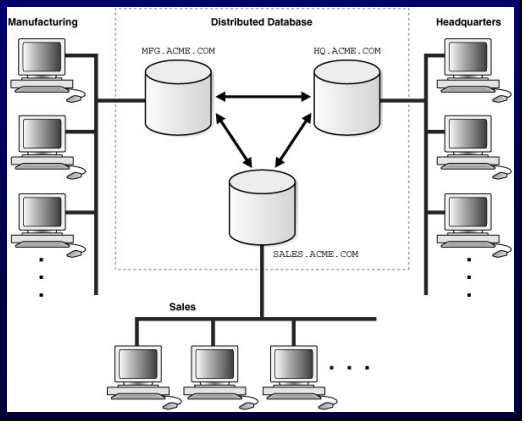
DBMS itself is still a centralized DBMS in which all the DBMS functionality, application program execution, and user interface processing is carried out on client machine. Gradually, DBMS systems started to exploit the available processing power at the user side, which led to client/server DBMS architectures.



Centralized and Client/Server Architectures for DBMSs;

Distributed Processing Database System:

A distributed database is a database that consists of two or more files located in different sites either on the same network or on entirely different networks. Portions of the database are stored in multiple physical locations and processing is distributed among multiple database nodes.



Course Contents

Two-Tier Client/Server Architectures for DBMSs:

Two main types of basic DBMS architectures were created on the Basic/Client Server Architecture underlying client/server framework: two-tier and three-tier.

Many of relational database management systems (RDBMSs) started as centralized systems. The system components that were first moved to the client side were the user interface and application programs. Because SQL provided a standard language for RDBMSs and this created a logical dividing point between client and server. Hence, the query and transaction functionality related to SQL processing remained on the server side. In such an architecture, the server is often called a query server or transaction server because it provides these two functionalities. In an RDBMS, the server is also often called an SQL server.

Course Contents

Two-Tier Client/Server Architectures for DBMSs:

The user interface programs and application programs can run on the client side. When DBMS access is required, the program establishes a connection to the DBMS (which is on the server side); once the connection is created, the client program can communicate with the DBMS. A standard called Open Database Connectivity (ODBC) provides an application programming interface (API), which allows client-side programs to call the DBMS, as long as both client and server machines have the necessary software installed.

Most DBMS vendors provide ODBC drivers for their systems. A client program can actually connect to several RDBMSs and send query and transaction requests using the ODBC API, which are then processed at the server sites. Any query results are sent back to the client program, which can process and display the results as needed. A related standard for the Java programming language, called JDBC, has also been defined. This allows Java client programs to access one or more DBMSs through a standard interface.

The architectures are called two-tier architectures because the software components are distributed over two systems: client and server.

Course Contents

Two-Tier Client/Server Architectures for DBMSs:

The architectures are called two-tier architectures because the software components are distributed over two systems: client and server.

Client Side computer <- User interface programs and application programs

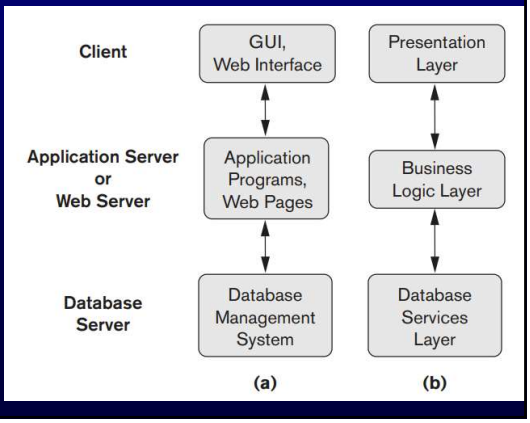
Server Side Computer <- Database, query and transaction functionality. So, the server is often called a query server or transaction server

Course Contents

Three-Tier and n-Tier Architectures for Web Applications:

Many Web applications use an architecture called the three-tier architecture, which adds an intermediate layer between the client and the database server, as shown in Figure.

1. **Clients:** user interfaces and Web browsers
2. **Middle Layer (application server or the Web server)**: application programs and storing business rules (procedures or constraints)
3. **Database Server:** Database, query and transaction functionality)



Course Contents

Three-Tier and n-Tier Architectures for Web Applications:

This intermediate layer or middle tier is called the application server or the Web server, depending on the application. This server plays an intermediary role by running application programs and storing business rules (procedures or constraints) that are used to access data from the database server. It can also improve database security by checking a client's credentials before forwarding a request to the database server. Clients contain user interfaces and Web browsers. The intermediate server accepts requests from the client, processes the request and sends database queries and commands to the database server, and then acts as a conduit for passing (partially) processed data from the database server to the clients, where it may be processed further and filtered to be presented to the users. Thus, the user interface, application rules, and data access act as the three tiers.

Course Contents

Three-Tier and n-Tier Architectures for Web Applications:

The presentation layer displays information to the user and allows data entry. The business logic layer handles intermediate rules and constraints before data is passed up to the user or down to the DBMS. The bottom layer includes all data management services. The middle layer can also act as a Web server, which retrieves query results from the database server and formats them into dynamic Web pages that are viewed by the Web browser at the client side. The client machine is typically a PC or mobile device connected to the Web.

Course Contents

Classification of Database Management Systems:

Course Contents

Classification of Database Management Systems:

Several criteria can be used to classify DBMSs.

1. Based on Data Model: relational, object, object-relational, NOSQL, key-value, hierarchical, network, and other.

2. Based on Number of users supported by the system: Single-user systems support only one user at a time and are mostly used with PCs. Multiuser systems, which include the majority of DBMSs, support concurrent multiple users.

3. Based on Number of sites over which the database is distributed: A DBMS is centralized if the data is stored at a single computer site. A centralized DBMS can support multiple users, but the DBMS and the database reside totally at a single computer site. A distributed DBMS (DDBMS) can have the actual database and DBMS software distributed over many sites connected by a computer network. Big data systems are often massively distributed, with hundreds of sites. The data is often replicated on multiple sites so that failure of a site will not make some data unavailable.

Course Contents

Classification of Database Management Systems:

Homogeneous DBMSs use the same DBMS software at all the sites, whereas heterogeneous DBMSs can use different DBMS software at each site. It is also possible to develop middleware software to access several autonomous preexisting databases stored under heterogeneous DBMSs.

4. Based on cost: Open source (free) DBMS products like MySQL and PostgreSQL that are supported by third-party vendors with additional services. Licenses - site licenses allow unlimited use of the database system with any number of copies running at the customer site. Another type of license limits the number of concurrent users or the number of user seats at a location. Standalone single-user versions of some systems like Microsoft Access are sold per copy or included in the overall configuration of a desktop or laptop. In addition, data warehousing and mining features, as well as support for additional data types, are made available at extra cost. It is possible to pay millions of dollars for the installation and maintenance of large database systems annually.

Course Contents

Classification of Database Management Systems:

5. General purpose or Special purpose. When performance is a primary consideration, a special-purpose DBMS can be designed and built for a specific application; such a system cannot be used for other applications without major changes. Many **airline reservations** and **telephone directory systems** developed in the past are special-purpose DBMSs. These fall into the category of online transaction processing (OLTP) systems, which must support a large number of concurrent transactions without imposing excessive delays.

Database Concepts and Architecture

Database system environment:

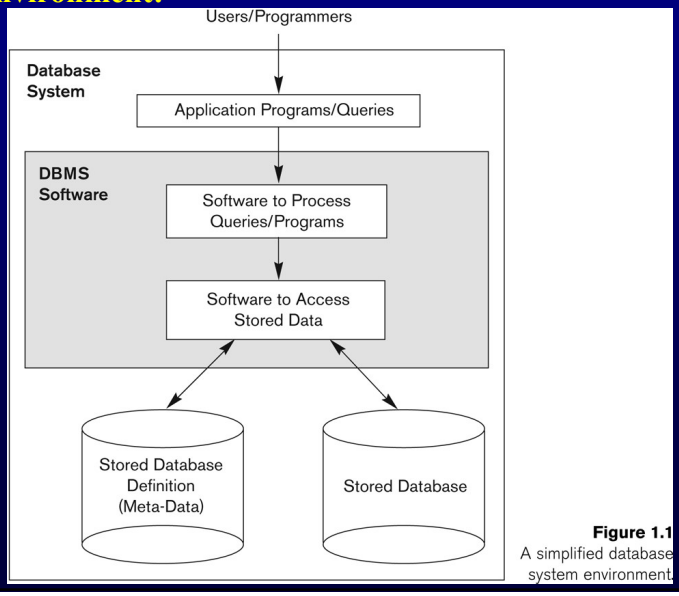


Figure 1.1
A simplified database system environment.