DATABASE MANAGEMENT SYSTEM

CO204

B. Tech. II CSE (Sem-4th)

COED

Credits: 5 (L:3 T:1 P:2)

Goals

- Learn about the foundations of Relational DBMS
  - Design methodology for databases and their structural correctness
  - Applying the theory behind various database models
  - Declarative programming: specify WHAT you want, not HOW to get it
  - Data independence
  - Recovery from crashes to a consistent state
  - Programming for concurrent execution: transactions
- Be able to create, access, and manipulate a database through SQL, PL/SQL and from an application
- Be able to understand and critically evaluate features of competing data management offerings
- Working in group settings to design and implement database projects

Outcome of the Course

1. Fluency in writing code in **SQL** for data definition, queries, updates.
2. Able to design the **entity-relationship model** for database design.
3. Able to apply the principles of **normalization** to relational database design.
4. Able to use the results of **database optimizer plans** analyze and tune database system performance by appropriate selection of indices.
5. Understanding of the concept of a database **transaction**, including atomicity, **concurrency, and recovery.**
6. Able to select appropriate **transaction isolation levels.**
7. Understanding of **SQL authorization** and its relationship to broader issues in database security.
8. Able to use **JDBC** to embed SQL database accesses in Java/web application code.

Daily life Applications uses DBMS

- Daily life uses Applications
  - Banking: transactions
  - Airlines: reservations, schedules
  - Universities: registration, grades
  - Sales: customers, products, purchases
  - Online retailers: order tracking, customized recommendations
  - Manufacturing: production, inventory, orders, supply chain
  - Human resources: employee records, salaries, tax deductions
- Databases touch all aspects of our lives

University Database Example

- Application program examples, for the University
  - Add new students, instructors, and courses
  - Register students for courses, and generate class rosters
  - Assign grades to students, compute grade point averages (GPA) and generate transcripts
- In the early days, database applications were built directly on top of file systems

Database Management System (DBMS)

- Databases can be very large
- To Manage the data
  - Store data
  - Update data
  - Answer questions about the data

- DBMS contains information about a particular enterprise
  - Collection of interrelated data
  - Set of programs to access the data
  - An environment that is both *convenient* and *efficient* to use

DBMS

- A DBMS is a system of programs

Includes facilities to:

1. Define and modify the database structure
2. Construct the database on a storage medium
3. Manipulate the database: queries and updates
4. Maintain integrity and security over the database by
   - Protecting data from inconsistency due to multiple concurrent users
   - Crash recovery
   - Access control

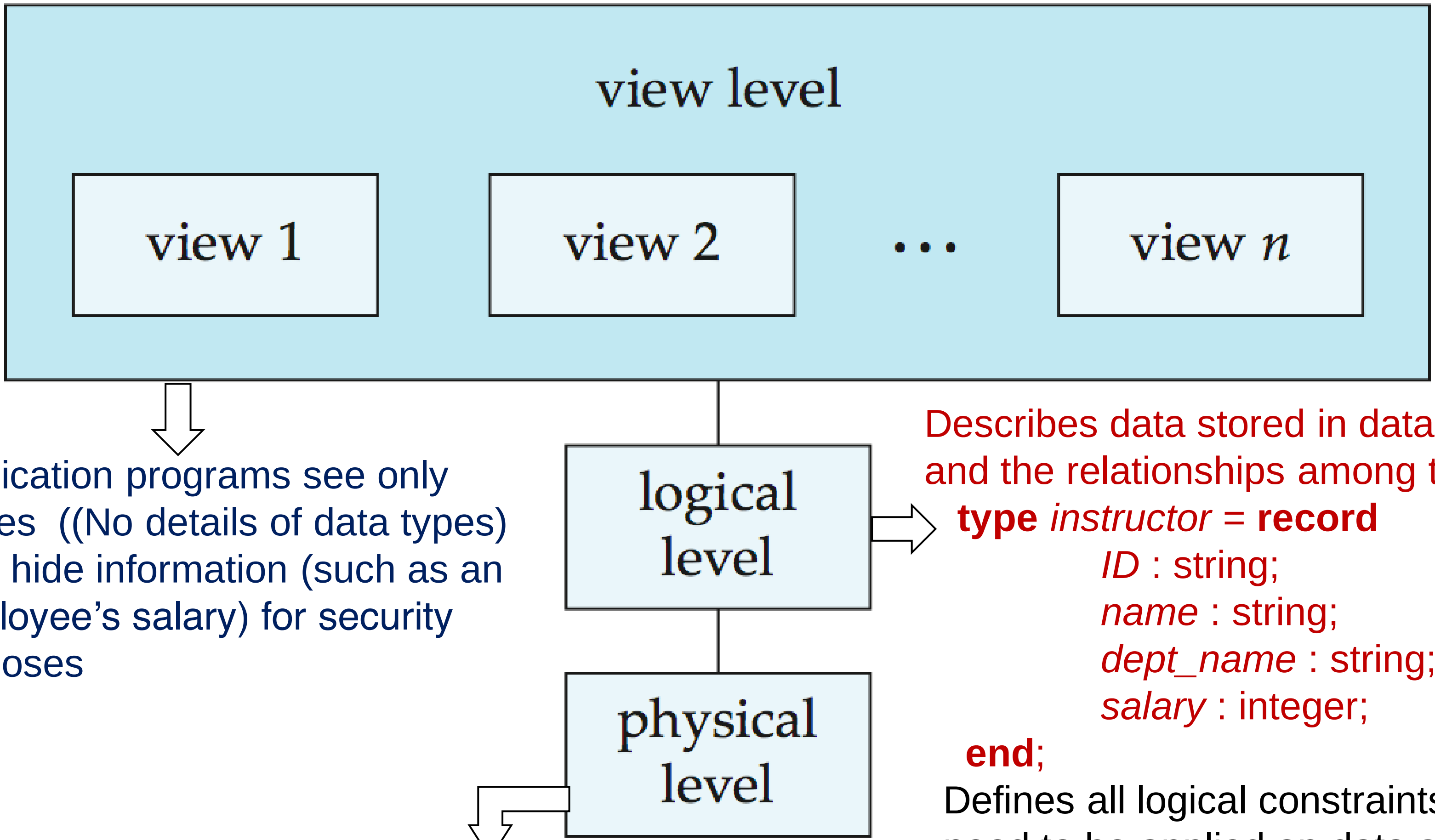
   Done using log file / user roles

Data Abstraction

- Probably the most important purpose of a DBMS
- Hides low-level details from the users of the system

View of Data

A High Level Data View for a database system



Application programs see only values ((No details of data types) Also hide information (such as an employee's salary) for security purposes

Describes data stored in database, and the relationships among the data

```
type instructor = record
        ID : string;
        name : string;
        dept_name : string;
        salary : integer;
end;
```

Defines all logical constraints that need to be applied on data stored Tables, views, Integrity constraints etc.

Describes how a record is stored on storage(tape/disk) like files (which file system), and indices etc.

Data Abstraction: Banking Example

- Logical level:
  - Provide an abstraction of *tables*
  - Two tables can be accessed:
    - *accounts*
      - Columns: account number, balance
    - *customers*
      - Columns: name, address, account number
- View level:
  - A teller (non-manager) can only see a part of the *accounts* table
    - Not containing high balance accounts

Data Abstraction: Banking Example

- Physical Level:
  - Each table is stored in a separate ASCII file
  - # separated fields
- Identical to what we had before ?
  - BUT the users are not aware of this
    - They only see the tables
    - The application programs are written over the tables abstraction
  - Can change the physical level without affecting users
  - In fact, can even change the logical level without affecting the *teller*

Instances and Schemas

- Similar to types and variables in programming languages
- **Schema**
  - **Analogous to type information of a variable in a program**
  - The **logical structure of the database**
  - **Designed when database doesn't exist at all**
  - **Very hard to do any changes once the database is operational**
  - **Does not contain any data or information**
  - Example: The database consists of information about a set of customers and accounts and the relationship between them
  - **Physical schema**:
    - Database design at the physical level
  - **Logical schema**:
    - Database design at the logical level

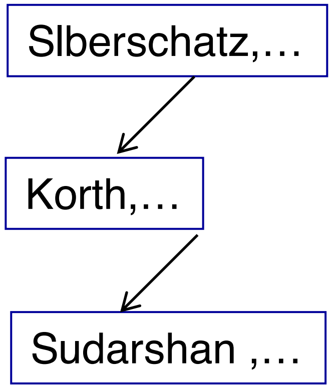
Instances and Schemas

- **Instance**
  - **Analogous to the value of a variable**
  - The actual content (or a state) of the database with data at a particular point in time
  - Snapshot of database
  - Tend to change with time
  - DBMS ensures that its every instance (state) must be a valid state
    - By keeping up to all validation, constraints and condition that database designers has imposed or it is expected from DBMS itself

Data Independence

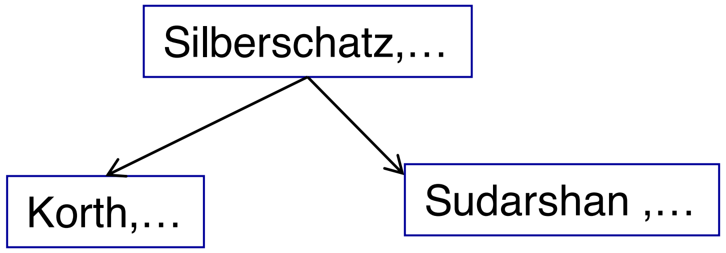
- One of the most important benefits of using a DBMS
- Applications insulated from how data is structured and stored
- In general, the interfaces between the various levels and components should be well defined so that changes in some parts do not seriously influence others
  - e.g. The capability to change the lower level structure of data without having to change the application programs at the next higher level

Data Dependence



```
Search ( name-asked : char[30] );
    s : Student-Record;
    . . .
Begin
    open ( student-file );
    while not end of file do
      begin
          read-a-record ( s );
          if  s.name = name-asked then
            begin
                  print ( s );
                  stop;
            end;
      end;
    print ( "No such a student." );
End.
```

Data Dependence



```
Search ( name-asked : char[30] );
     root-record  : student-record;
begin
     root-record := root record;
     Find-It (name-asked, root-record );
end.
```

```
Find-It ( name-asked : char[30];
             root : student-record );
begin
     if root = null then
       begin
             print ( "No such a student." );
             stop;
       end;
     if root.name = name-asked then
       begin
             print( root );
             stop;
       end
     else if root.name < name-asked then
                  find-it ( name-asked,
             root.left );
             else
                 find-it ( name-asked, root.right );
end.
```

Data Independence

- Probably the most important purpose of a DBMS
- Hides low-level details from the users of the system

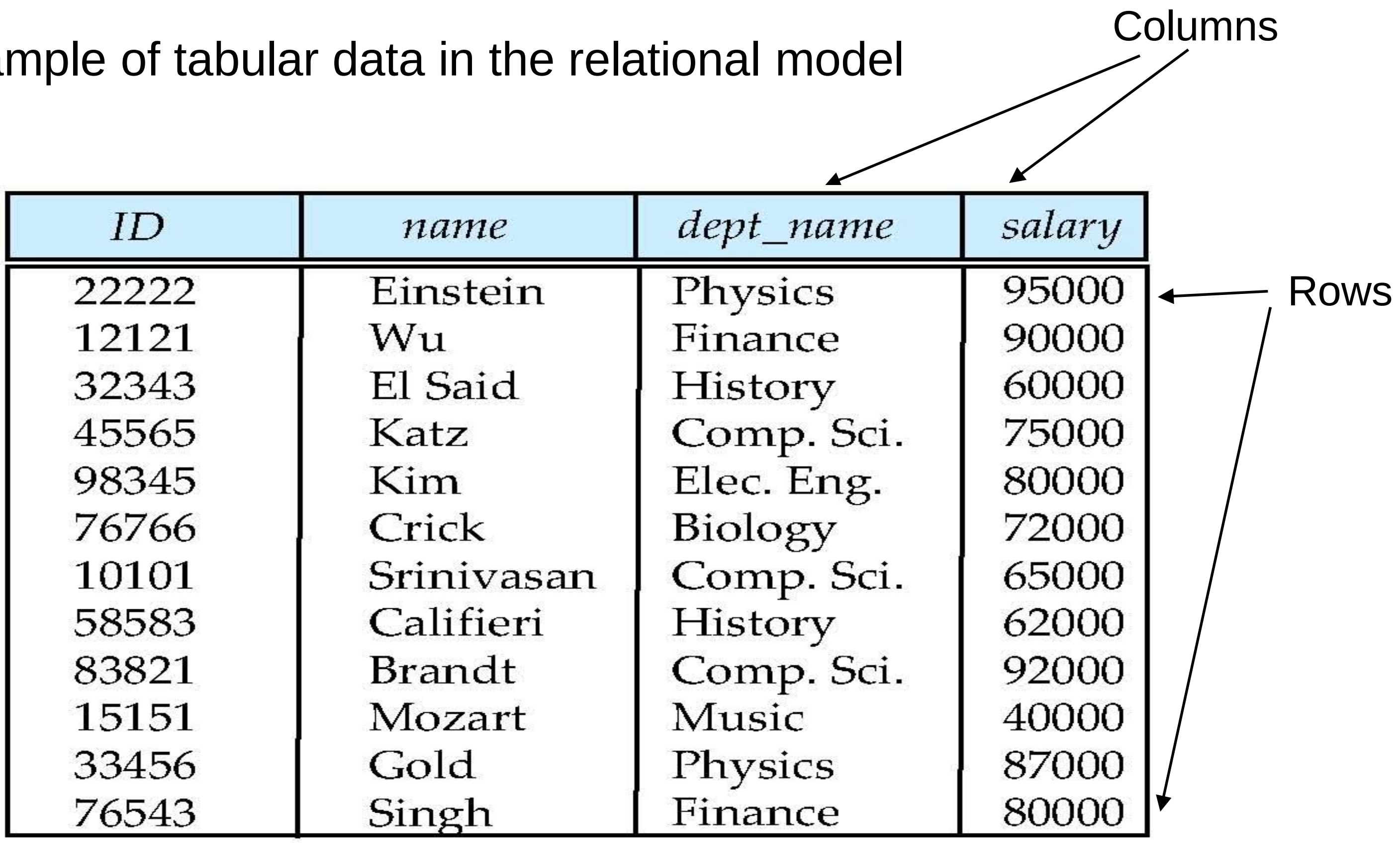
- **Physical Data Independence**
  - If, modify the physical schema
    - No need to change the logical schema
  - Applications depend on the logical schema
  - Query and update logical structure, not physical structure
- **Logical data independence**
  - Protection from changes in logical structure of data
  - If logical structure changes
    - Then, create view with old structure
  - Works fine for queries, but might be tricky for updates

Data Models

- A collection of tools for describing
  - Data
  - Data relationships
  - Data semantics
  - Data constraints
- Types
  - Relational model
  - Entity-Relationship data model (mainly for database design)
  - Object-based data models (Object-oriented and Object-relational)
  - Semistructured data model (XML)
  - Other **older** models:
    - Network model
    - Hierarchical model

Relational Model

- Relational model
- Example of tabular data in the relational model


Columns
Rows

ID	*name*	*dept_name*	*salary*
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
76766	Crick	Biology	72000
10101	Srinivasan	Comp. Sci.	65000
58583	Califieri	History	62000
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

(a) The *instructor* table

A Sample Relational Database

ID	*name*	*dept_name*	*salary*
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
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15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

(a) The *instructor* table

dept_name	*building*	*budget*
Comp. Sci.	Taylor	100000
Biology	Watson	90000
Elec. Eng.	Taylor	85000
Music	Packard	80000
Finance	Painter	120000
History	Painter	50000
Physics	Watson	70000

(b) The *department* table

Data Definition Language (DDL)

- Specification notation for defining the database schema

  Example: **create table** *instructor* (
  ID **char**(5),
  name **varchar**(20)**,**
  dept_name **varchar**(20),
  salary **numeric**(8,2))

- DDL compiler generates a set of table templates stored in a ***data dictionary***
- Data dictionary contains metadata (i.e., data about data)
  - Database schema
  - Integrity constraints
    - Primary key (ID uniquely identifies instructors)
    - Referential integrity (**references** constraint in SQL)
      - e.g. *dept_name* value in any *instructor* tuple must appear in *department* relation
  - Authorization

SQL

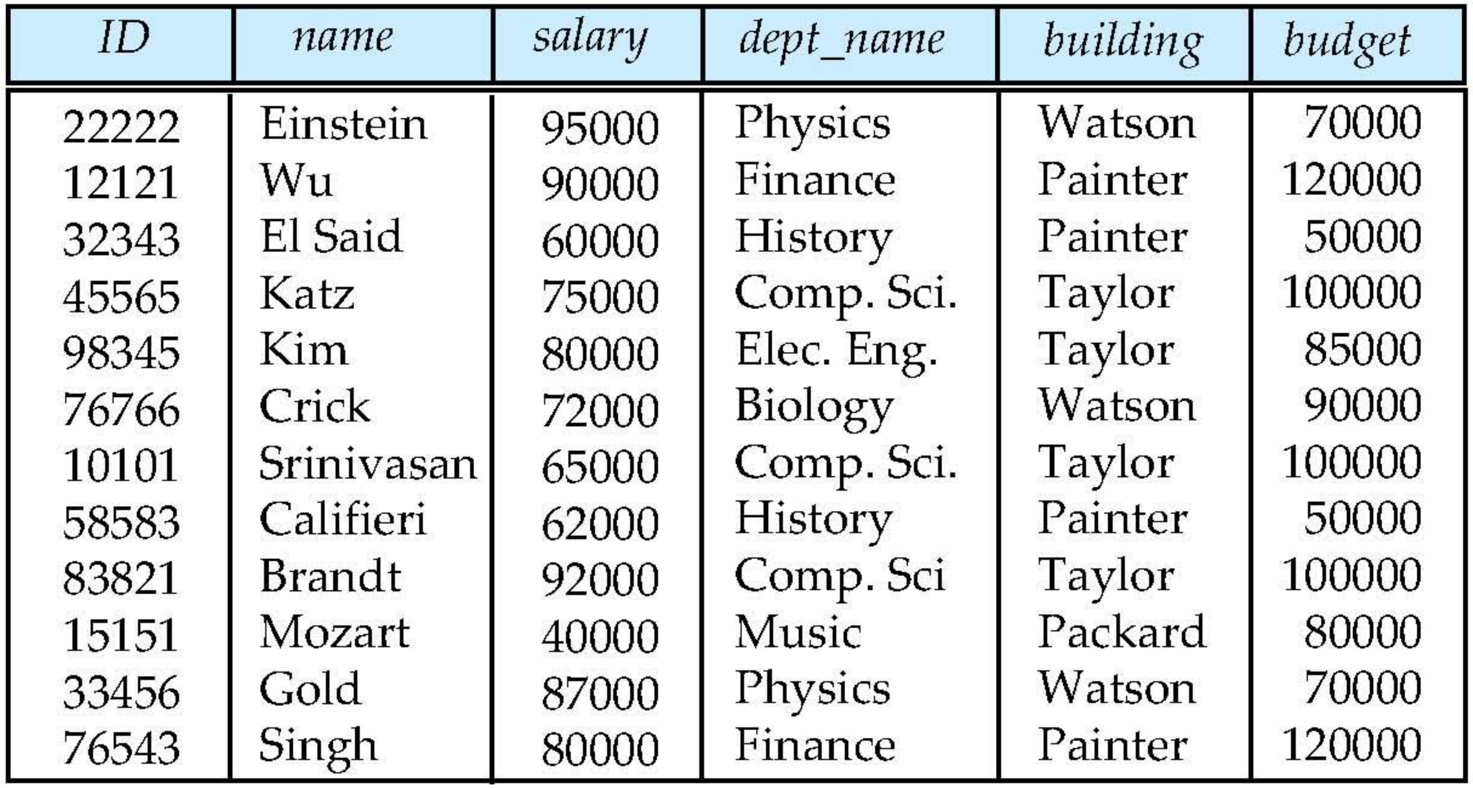
- **SQL**: widely used non-procedural language
  - Example: Find the name of the instructor with ID 22222
    select *name*
    from *instructor*
    where *instructor.ID* = '22222'
  - Example: Find the ID and building of instructors in the Physics dept.

    select *instructor*.*ID*, *department*.*building*
    from *instructor*, *department*
    where *instructor.dept_name* = *department.dept_name* **and**
    department.dept_name = 'Physics'

- Application programs generally access databases through one of
  - Language extensions to allow embedded SQL
  - Application program interface (e.g., ODBC/JDBC) which allow SQL queries to be sent to a database

Database Design?

- Is there any problem with this design?



ID	*name*	*salary*	*dept_name*	*building*	*budget*
22222	Einstein	95000	Physics	Watson	70000
12121	Wu	90000	Finance	Painter	120000
32343	El Said	60000	History	Painter	50000
45565	Katz	75000	Comp. Sci.	Taylor	100000
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Design Approaches

- Normalization Theory
  - Formalize what designs are bad, and test for them
- Entity Relationship Model
  - Entity
  - Relation
  - Models an enterprise as a collection of *entities* and *relationships*
  - Represents diagrammatically by an *entity-relationship diagram*

ER Model

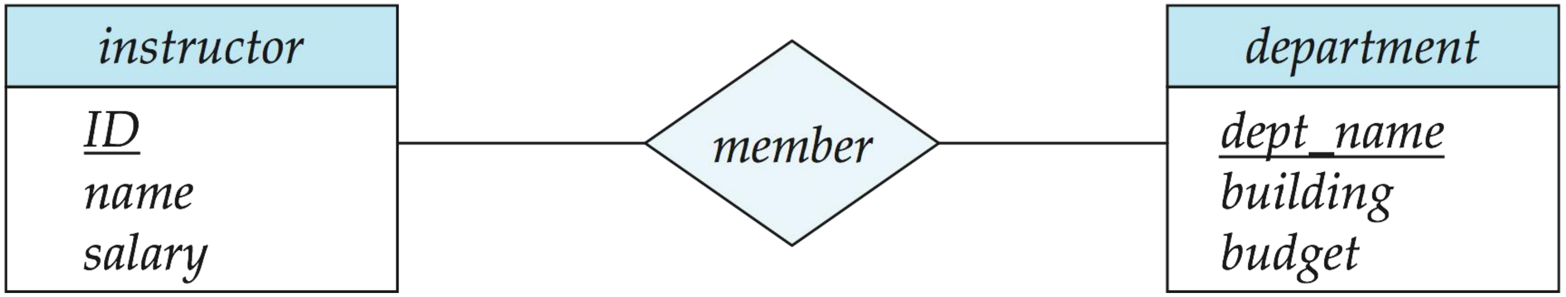
- Entity
  - A “thing” or “object” in the enterprise that is distinguishable from other objects
    - Described by a set of *attributes*
    - Examples: Korth, CO402
    - Form entity sets with other entities of the same type that share the same properties
    - Set of all people, set of all classes

ER Model

- Relation
  - Relate 2 or more entities
    - E.g. Korth book used at SVNIT Computer Engg. Branch
  - Form relationship sets with other relationships of the same type that share the same properties
    - Customers have accounts at Branches
  - Can have attributes:
    - Customer has multiple accounts may have an attribute start-date
  - Can involve more than 2 entities
    - Employee works at Branch as Manager

The Entity-Relationship Model

- Example Partial Diagram:

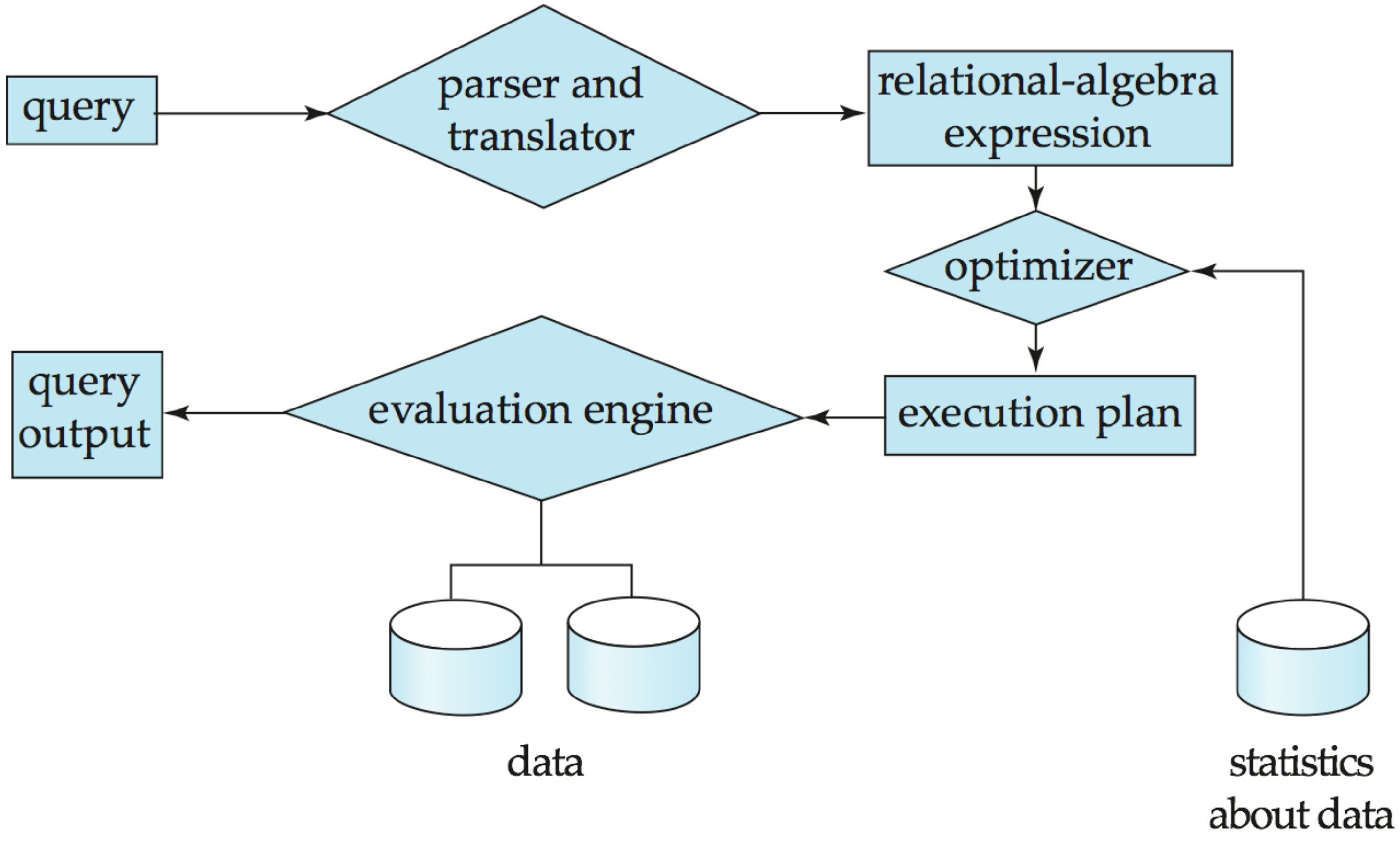


Storage Management

- **Storage manager** is a program module that provides the interface between the low-level data stored in the database and the application programs and queries submitted to the system
- The storage manager is responsible to the following tasks:
  - Interaction with the file manager
  - Efficient storing, retrieving and updating of data
- Issues:
  - Storage access
  - File organization
  - Indexing and hashing

Query Processing

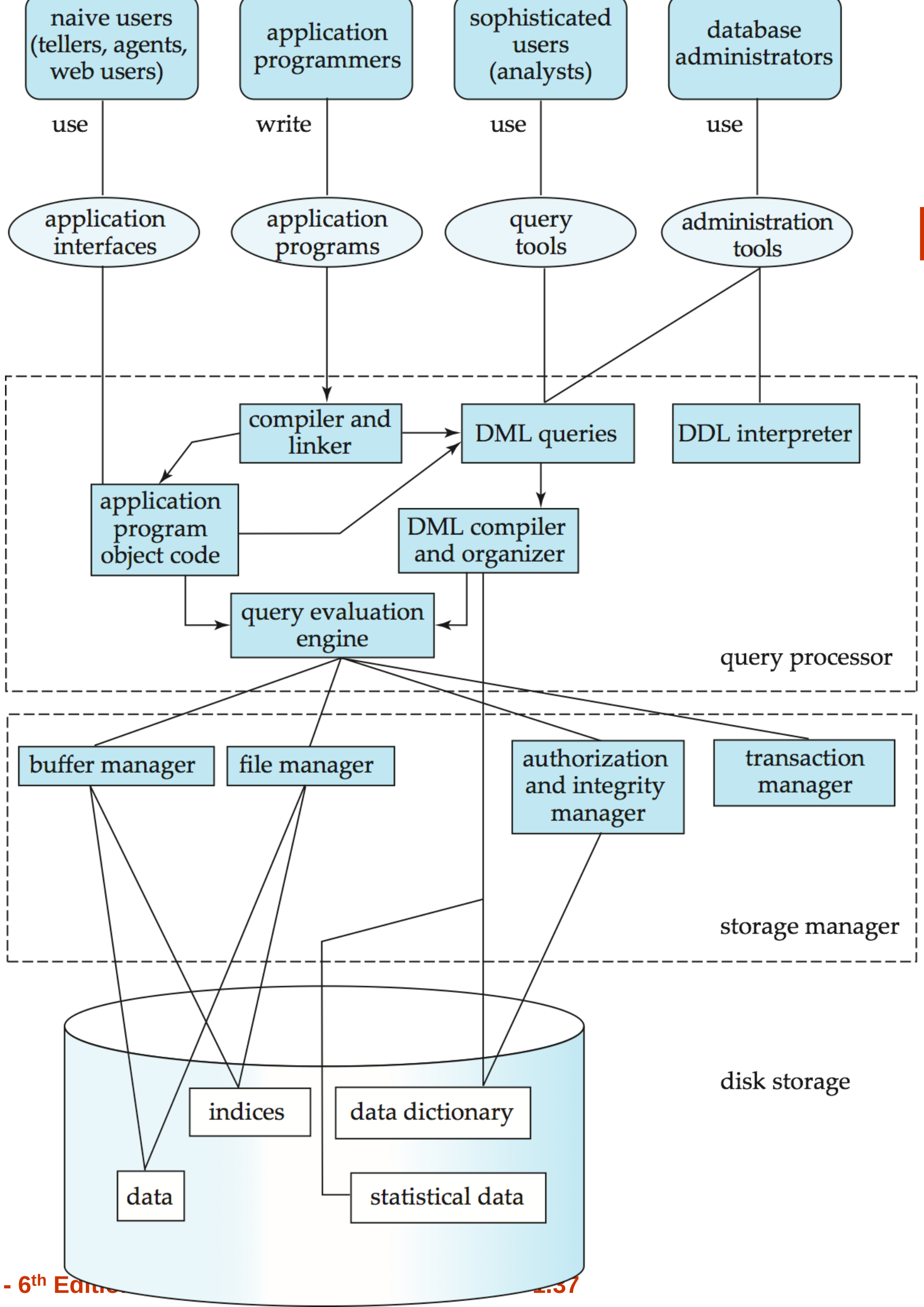
1. Parsing and translation
2. Optimization
3. Evaluation



Transaction Management

- What if the system fails?
- What if more than one user is concurrently updating the same data?
- **Transaction**
  - A collection of operations that performs a single logical function in a database application
- **Transaction-management component**
  - Ensures that the database remains in a consistent (correct) state despite system failures (e.g., power failures and operating system crashes) and transaction failures
- **Concurrency-control manager**
  - Controls the interaction among the concurrent transactions, to ensure the consistency of the database

Database System Internals



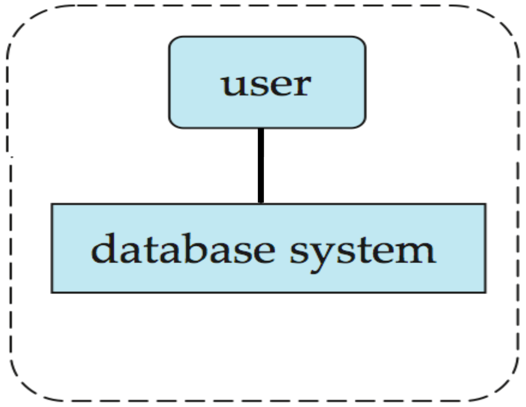
Database Architecture

The architecture of a database systems is greatly influenced by
the underlying computer system on which the database is running:

- Centralized
  - All the DBMS functionality, application program execution and user interface processing of dumb terminals were carried out on a single centralized machine like mainframe machine
- Client-server
  - A client is typically a user machine not dumb terminal that provides user interface capabilities and local processing
  - A server is a system containing both hardware and software that can provide services to the client machines
- Parallel (multi-processor)
- Distributed

Client Server Architecture

- Single tier or Multi tier
- n-tier architecture divides the whole system into related but independent n modules, which can be independently modified, altered, changed or replaced
- 1-tier architecture
  - DBMS is the only entity where user directly sits on DBMS and uses it
  - Any changes done here will directly be done on DBMS itself
  - Does not provide handy tools for end users and preferably database designer and programmers use single tier architecture

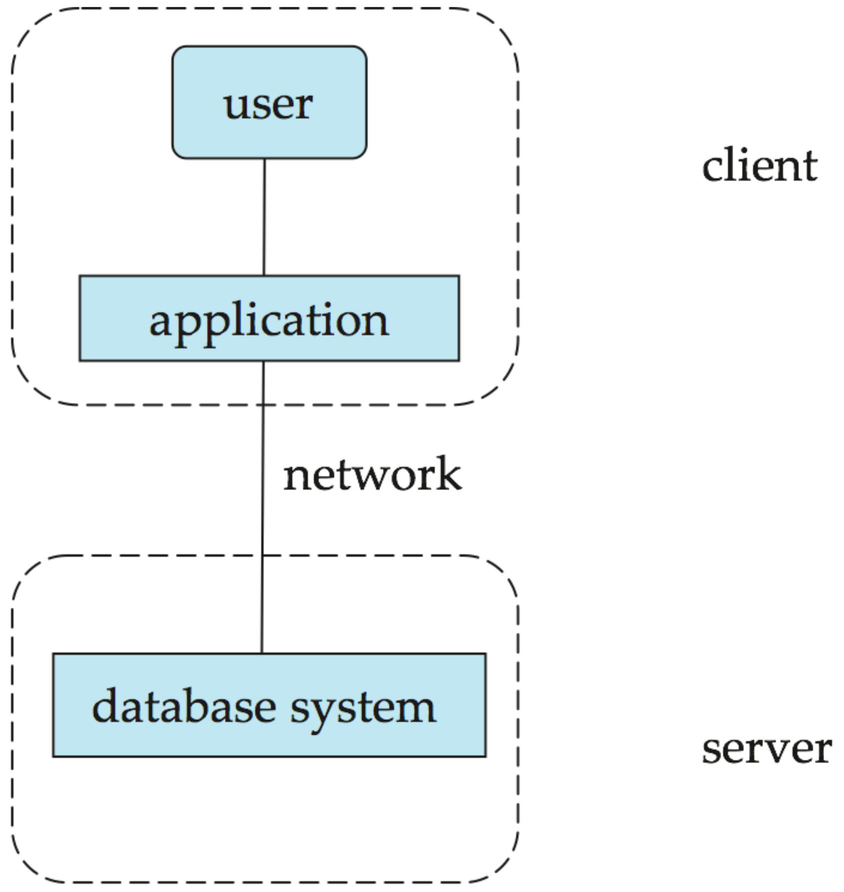


User with editor to access the database

Only database along with its query processing, all relations and their constraints

Client Server Architecture

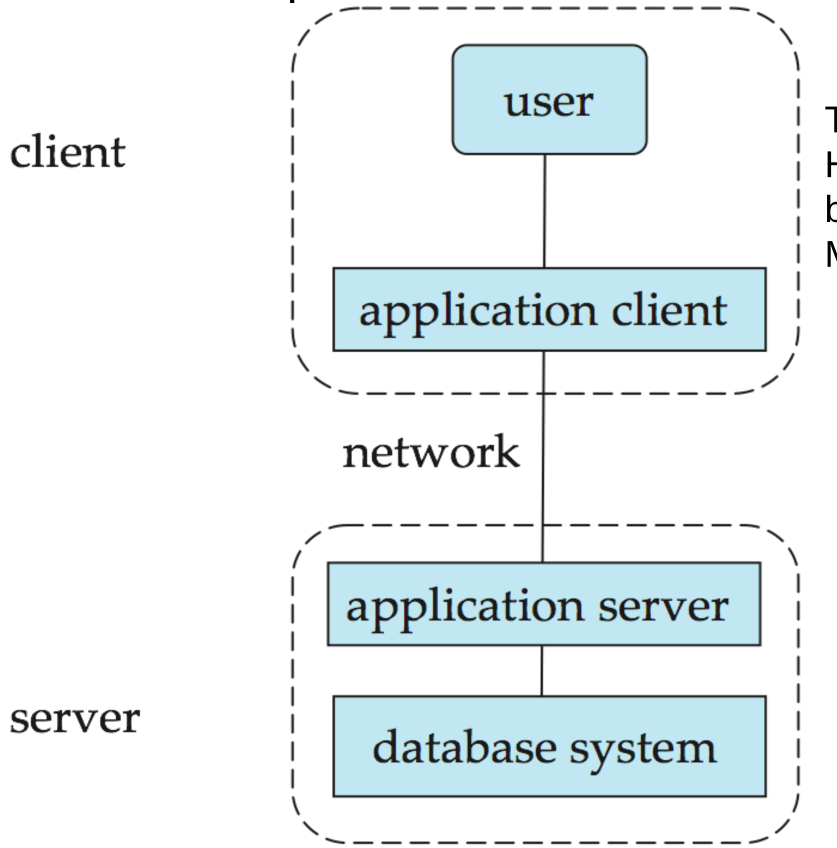
- Two-tier architecture
  - Must have some application, which uses the DBMS
  - Programmers use 2-tier architecture where they access DBMS by means of application
  - Application tier is entirely independent of database in term of operation, design and programming



(a) Two-tier architecture

DBMS Application Architecture

- Three-tier Architecture
  - Most widely used architecture
  - Separates it tier from each other on basis of users



(b) Three-tier architecture

This tier is everything for user
He/she doesn't know about any existence/form of database beyond this layer
Multiple views of database can be provided by application

Application server and program which access database
For a user this application tier works as abstracted view of database

Only database along with its query processing, all relations and their constraints

History of Database Systems

- **Before 1950s :**
  - Data was stored as paper records
  - Lot of man power involved
  - Lot of time was wasted
    - e.g. when searching
  - Inefficient
- **1950s and early 1960s:**
  - Data processing using magnetic tapes for storage
    - Tapes provided only sequential access
  - Punched cards for input, updated new tape will be used as master tape
  - Backup is considered as grand father, father and son relation

History (cont.)

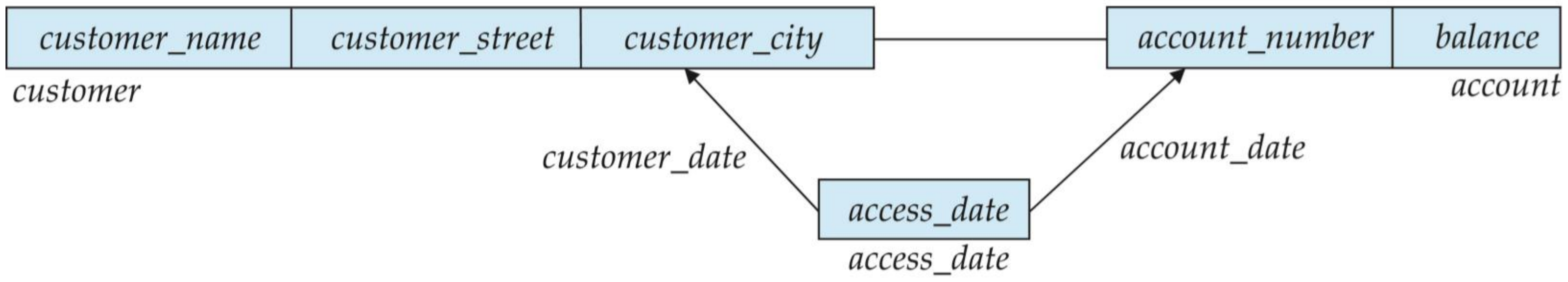
- **Late 1960s and 1970s:**
  - Hard disks allowed direct access to data
  - Data stored in files, known as File Processing System
    - Network and hierarchical data models in widespread use

History (cont.)

- **Network data models**
  - Data are represented by collections of *records*
    - Records and their fields are represented as *record type*

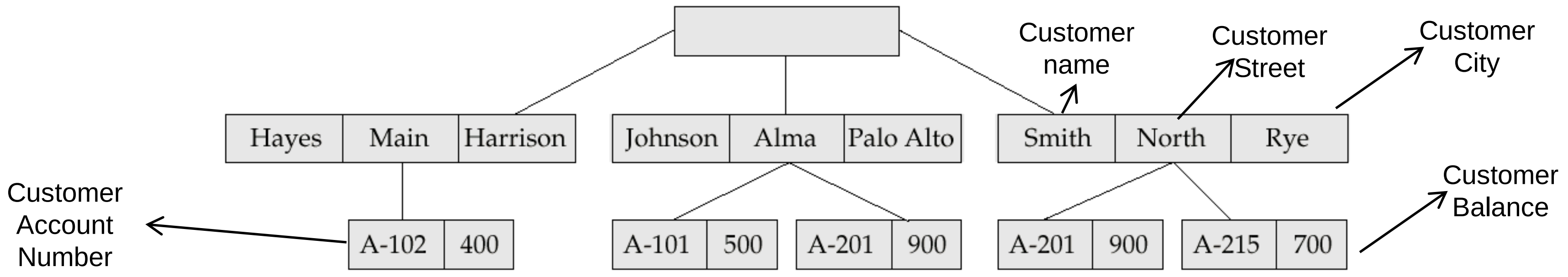
```
type    customer = record               type    account = record
        customer-name: string;                  account-number: integer;
        customer-street: string;                balance: integer;
        customer-city: string;
end                     end
```

  - Relationships among data are represented by *links*
    - Restrictions on links depend on whether the relationship is many-many, many-to-one, or one-to-one



History (cont.)

- **Hierarchical data models**
  - Consists of a collection of *records* which are connected to one another through *links* in the form of a *rooted tree*
    - Record – A collection of fields, each of which contains only one data value
    - Link - An association between precisely two records
  - No cycles in the underlying graph
  - Relationships formed in the graph must be such that only one-to-many or one-to-one relationships exist between a parent and a child.
  - The hierarchical model differs from the network model in that the records are organized as collections of trees rather than as arbitrary graphs



History (cont.)

- **Late 1960s and 1970s:**
  - Hard disks allowed direct access to data
  - Data stored in files, known as File Processing System
    - Network and hierarchical data models in widespread use
  - Ted Codd defined the relational data model
    - Codd—Mathematician who was working at IBM
    - Convinced that there was a more theoretically rigorous way to represent data on databases and to allow these databases to be accessed without complex programming
    - Thus arose the relational database model, which ushered in the era of RDBMS dominance
    - For a generation of database professionals—more than 25 years—the relational database has reigned supreme
    - IBM Research begins System R prototype
  - High-performance (for the era) transaction processing

History (cont.)

- **1980s:**
  - Research relational prototypes evolved into commercial systems
    - SQL becomes industrial standard
  - Parallel and distributed database systems
  - Object-oriented database systems
- **1990s:**
  - Large decision support and data-mining applications
  - Large multi-terabyte data warehouses
  - Emergence of Web commerce
- **Early 2000s:**
  - XML and XQuery standards
  - Automated database administration
- **Later 2000s:**
  - Giant data storage systems
    - Google BigTable, Yahoo PNuts, Amazon, ..

History (cont.)

- **Current:**
  - Graph Database
  - Columnar Database
  - NoSQL databases, especially those based on Amazon's DynamoDB
    - Explicitly designed to allow the database to continue operating in the presence of a network partition by sacrificing strict consistency
    - Instead, such a database offers eventual consistency
    - Created databases which can only be queried effectively by experienced programmers
  - BDaaS (Big Data as a Service)

Tools

- Commercial DBMS
  - IBM DB2
  - Oracle
  - Microsoft SQL Server
  - Sybase
  - IBM Informix
- Free DBMS
  - MySQL
  - PostgreSQL

Topics

Chapter
1. Introduction
Part 1: Relational Databases
2. Introduction to the Relational Model
3. Introduction to SQL
4. Intermediate SQL
5. Advanced SQL
6. Formal Relational Query Languages
Part 2: Database Design
7. Database Design: The Entity-Relationship Approach
8. Relational Database Design
9. Application Design
Part 3: Data Storage and Querying
10. Storage and File Structure
11. Indexing and Hashing
12. Query Processing
13. Query Optimization
Part 4: Transaction Management
14. Transactions
15. Concurrency Control
16. Recovery System
Part 5: System Architecture (Intro)
17. Database System Architectures
18. Parallel Databases
19. Distributed Databases
Part 6: Data Warehousing, Mining, and IR (Intro)
20. Data Mining
21. Information Retrieval
Part 8: Specialty Databases (Intro)
22. Object-Based Databases
23. XML

Tutorial Questions

1. Explain the disadvantages of conventional file system.
2. Explain programming language classification with examples of languages.
3. Enlist different data models.
4. Explain the different users of DBMS.
5. Draw the history hierarchy of DBMSs.
6. Explain the concept of physical data independence and its importance in database systems.
7. Two disadvantages associated with database systems.

End of Chapter 1

Chapter 2 Relational Model