Introduction

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San Jose State University

CS157a – Database Mgmt Systems

CS 157a: Database Mgmt Systems

Instructor: Dr Ramin Moazeni, Ramin.Moazeni@sjsu.edu

- Office hours: after class (or by appointment)

Course web site: https://sjsu.instructure.com

Texts and readings:

- Ramakrishnan & Gerke, *Database Management Systems*, 3rd ed.
- For SQL: Greenspun, *SQL for Nerds* (http://philip.greenspun.com/sql/index.html)
- Other books may be useful:
  - Elmasri, Navathe. "Fundamentals of Database Systems," Latest Edition
- Oracle References
  - Oracle SQL Reference
  - Oracle SQL*Plus User's Guide and Reference
  - Online Oracle Documentations
- Various papers and readings
- Prerequisites:
  - CS 146 (with a grade of "C-" or better); Computer Science, Applied and Computational Math, Forensic Science: Digital Evidence, or Software Engineering majors only; or instructor consent.

Course Format and Grading

- Quizzes: 10%
- HW Assignments: 20% (Individual)
- Project: 20% (Group)
  - Specification will be provided later
- Midterm exam: 25% (Individual)
- Final exam: 25% (Individual)

Important Dates

- Class starts Tuesday, June 4
- Academic Holiday
  - Independence Day, July 4 (No Class)
- Midterm Exam: Tuesday, July 9 (ONLINE)
- Class ends Thursday, Aug 8
- Final Exam: Thursday, Aug 8 (ONLINE)

Course Outline (may vary slightly)

Outline

- ER Data model
- The relational data model
- Map ER to Relational model
- Extended ER
- SQL
- OO & ORDBMS
- Application Programming (DB connectivity)
- XML, JSON, XML Schema
- Normalization
- Transactions
- DB Security
- Spatial DBs – If time permits
- NoSQL – If time permits

Cheating/Plagiarism

- Cheating is a serious offense.
- Cheating includes copying on exams or written assignments; obtaining advance copies of exams; outsourcing assignments or project work; and copying material from the web and including on assignments without proper attribution.
- You may discuss concepts with your classmates. However, when it comes to writing the assignment or the program (even just the 'pseudo-code'), you must do it yourself
- First incident of cheating will result in a 0 on that assignment or exam. Second incident will result in a F for the class.
- Please see the university's policy regarding academic integrity: http://www.sjsu.edu/senate/docs/S07-2.pdf

Outline for Today's Lecture

- Overview of database systems
  - Recommended reading: Introduction of **SQL for Web Nerds,** by Philip Greenspun http://philip.greenspun.com/sql/
  - Read Chapter 1 of the textbook
- Course outline
- What the course is about

What *Is* a Database Management System ?

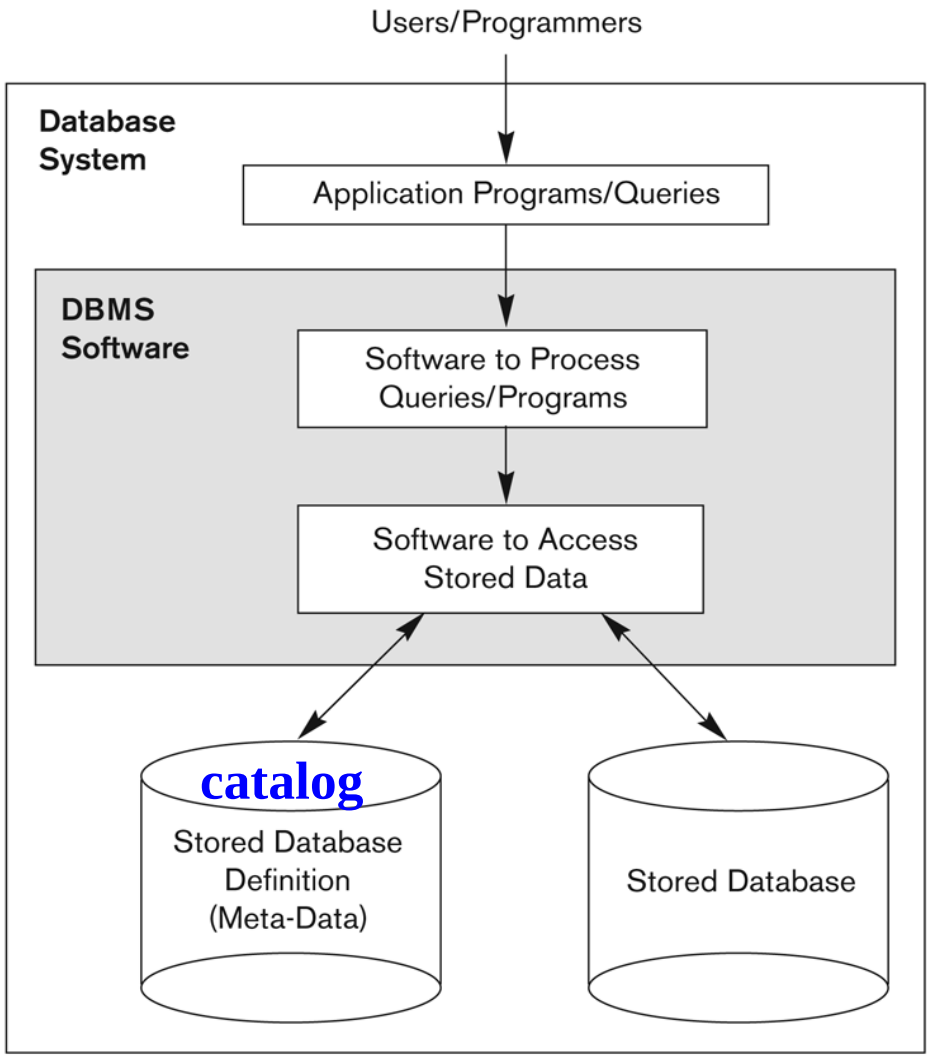
- Database: collection of files that store the data
  - Entities: students, faculty, courses and classroom
  - Relationships: between entities
    - Students taking courses
    - Faculty teaching courses
- DataBase Management System = DBMS
  - Software that Manages the DB
  - A big program that accesses and updates those files
- Relational DBMS = RDBMS
  - DBMS that is based on a relational model

Examples of DBMS Usage

- Airlines: reservations and schedules (Expedia)
- Universities: student info, grades
- Banking: customer info and accounts
- Credit Cards: customer info, transactions
- Sales: customer info, inventory (Amazon, EBay)
- Government: taxes, census

Example: Internet Movie Database (IMDB)

How is a RDBMS used ?



Databases are self-describing: catalog describes the structure of the data stored in the DB

Example of a Traditional Database Application

- Suppose we are building a system to store information about:
  - students
  - courses
  - professors
  - who takes what, who teaches what

Can we do it without a DBMS ?

Yes…Start by storing the data in files:

students.txt courses.txt professors.txt

Now write C or Java programs to implement specific tasks (i.e store, modify and query)

Doing it without a DBMS...

- Enroll “John Smith” in “CS444”:

Write a program to do the following:

Read ‘students.txt’
Read ‘courses.txt’
Find&update the record “John Smith”
Find&update the record “CS444”
Write “students.txt”
Write “courses.txt”

Problems without an DBMS…

- System crashes:

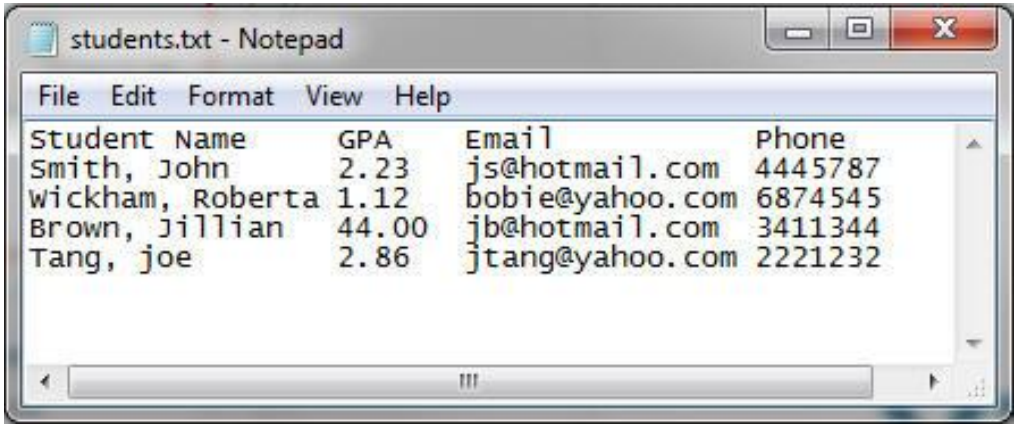
  - What is the problem ?
- Large data sets (say 50TB)
  - What is the problem ?
- Simultaneous access by many users
- Enforcing Constraints
- Scalability
- Security

Enforcing Constraints

- With the text file solution, there is no way to enforce integrity constraints on the data. In other words people can put bad data into the text file.

- In contrast, a DBMS allows us to enforce all kinds of constraints. This really helps (but does not guarantee) that our data is correct.

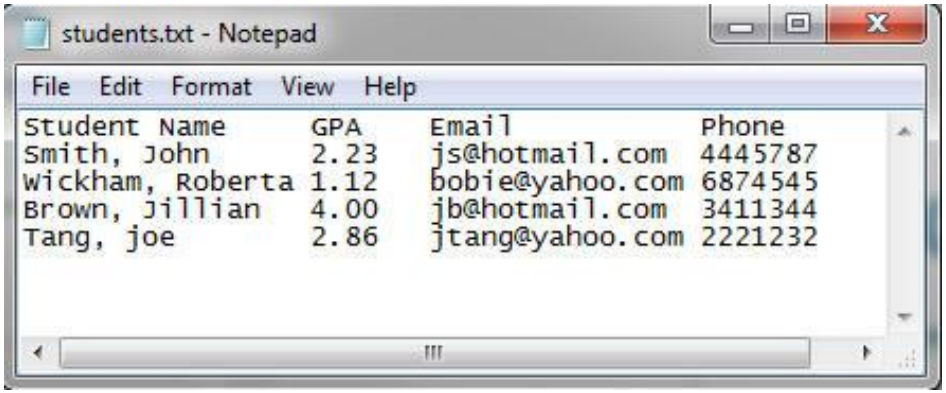
A typo gives Jillian Brown a GPA of 44.00



Scalability

- The text file solution might work for small datasets. What happens when we have big datasets?

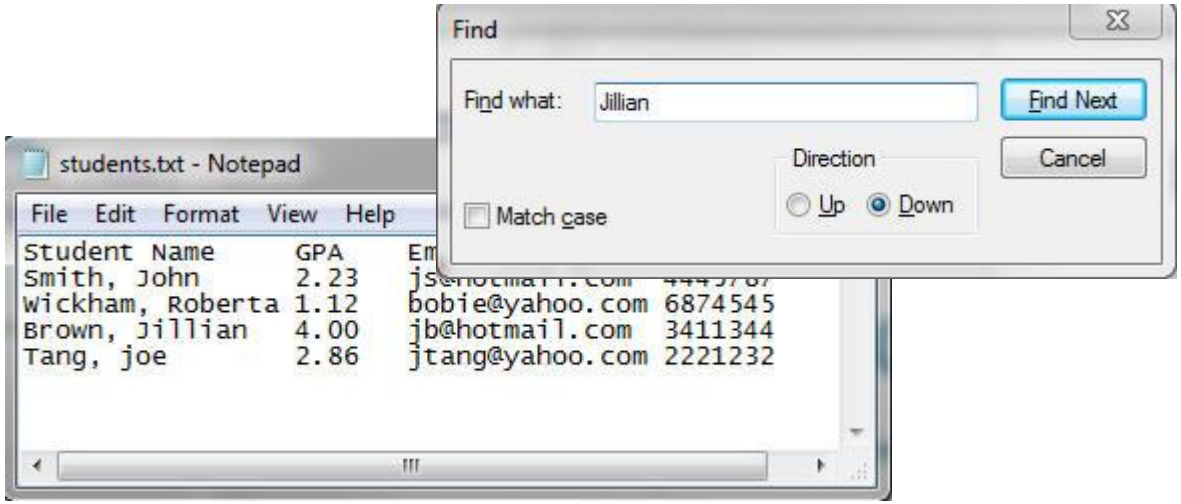
- Most real world datasets are so large that we can only have a small fraction of them in main memory at any time, the rest has to stay on disk.



Query Expressiveness

- The text file solution would allows to search for keywords or certain numbers (slowly).

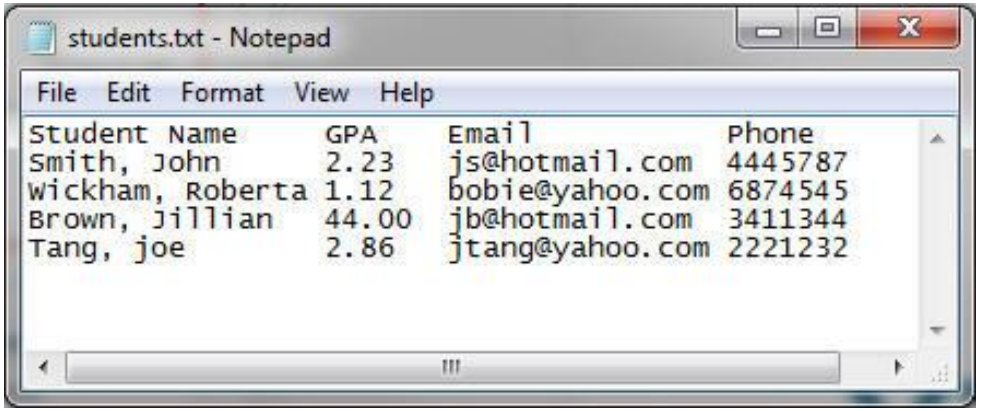
- With a DBMS I can search with much more expressive queries. For example I can ask.. "*Find all students whose GPA is greater than 2.5, and who don't own a phone*" or "*what is the average GPA of the students*"



Query Expressiveness II

- Could write some program that might allow more expressive queries on the text file, but it would be tied into the structure of my data and the operating system etc..

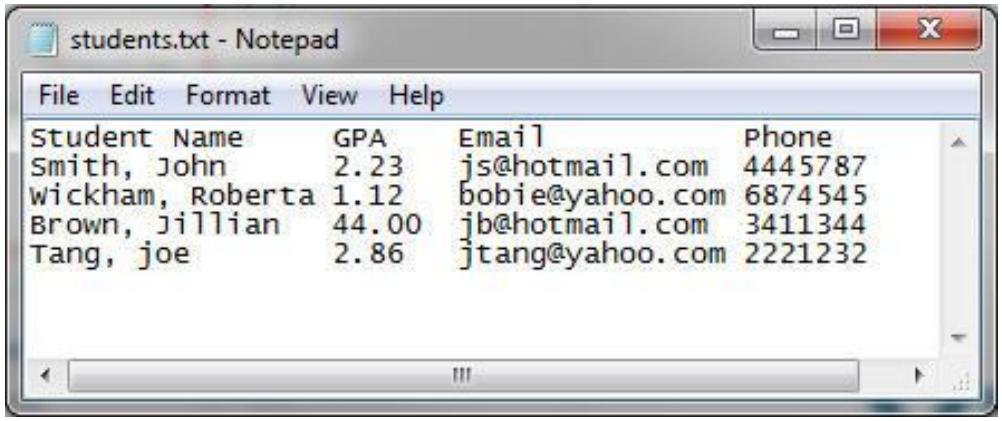
- With a DBMS we are completely isolated from the physical structure of our data. If we change the structure of our data (by adding a field, for example) or moving from a PC to a Mac, nothing changes at the front end!



Different Views

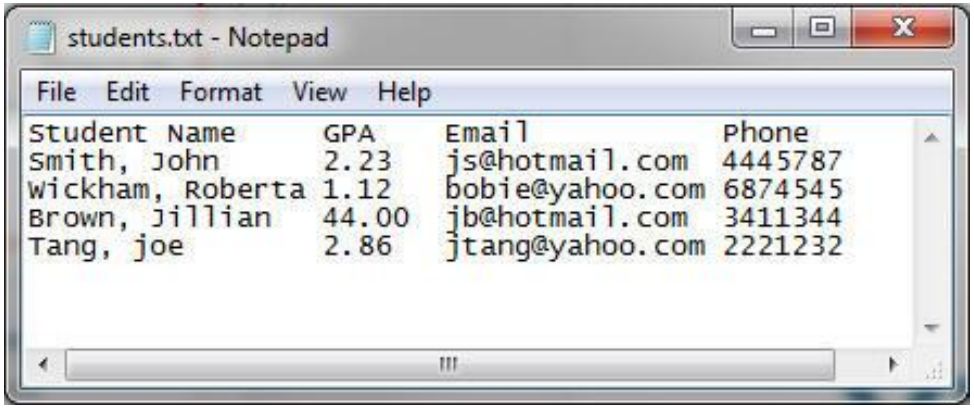
- The text file solution only allows one view of the data.

- With a DBMS, could arrange for different people to have different views of the data. For example, a professor can see everything, while student can see only his/her data, and a TA can see data for students in his/her section, etc.



Concurrency

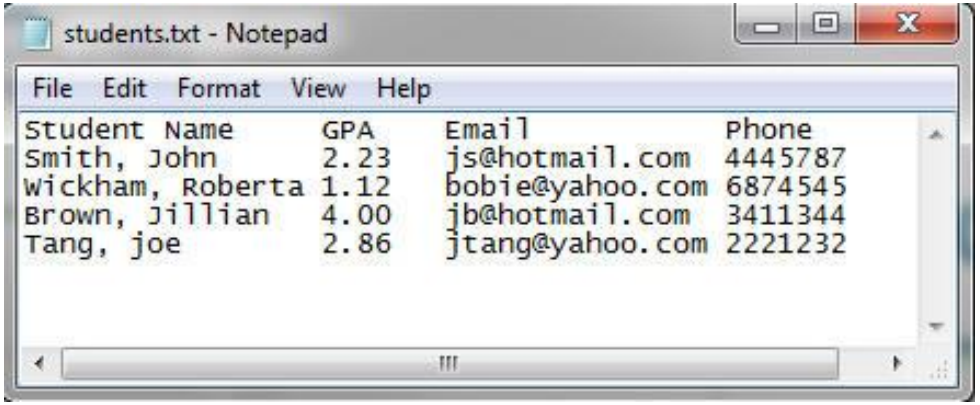
- Suppose the text file is being modified at the same time by multiple users (i.e professor and the TA)
- A DBMS will automatically make sure that this kind of thing cannot happen.



Security

- Suppose the text file on UNIX account, and a student hacks in and changes their grades…

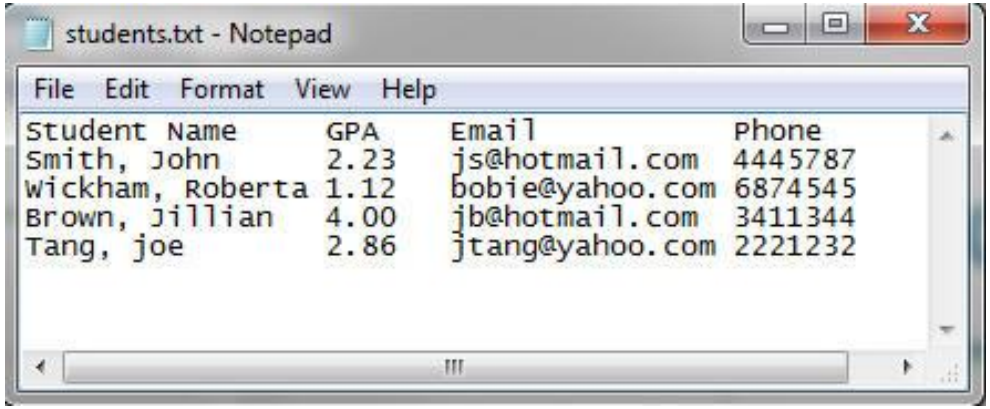
- A DBMS will allow multiple levels of security.
  - Enforce security policies for users to access different subset of data



Crash Recovery

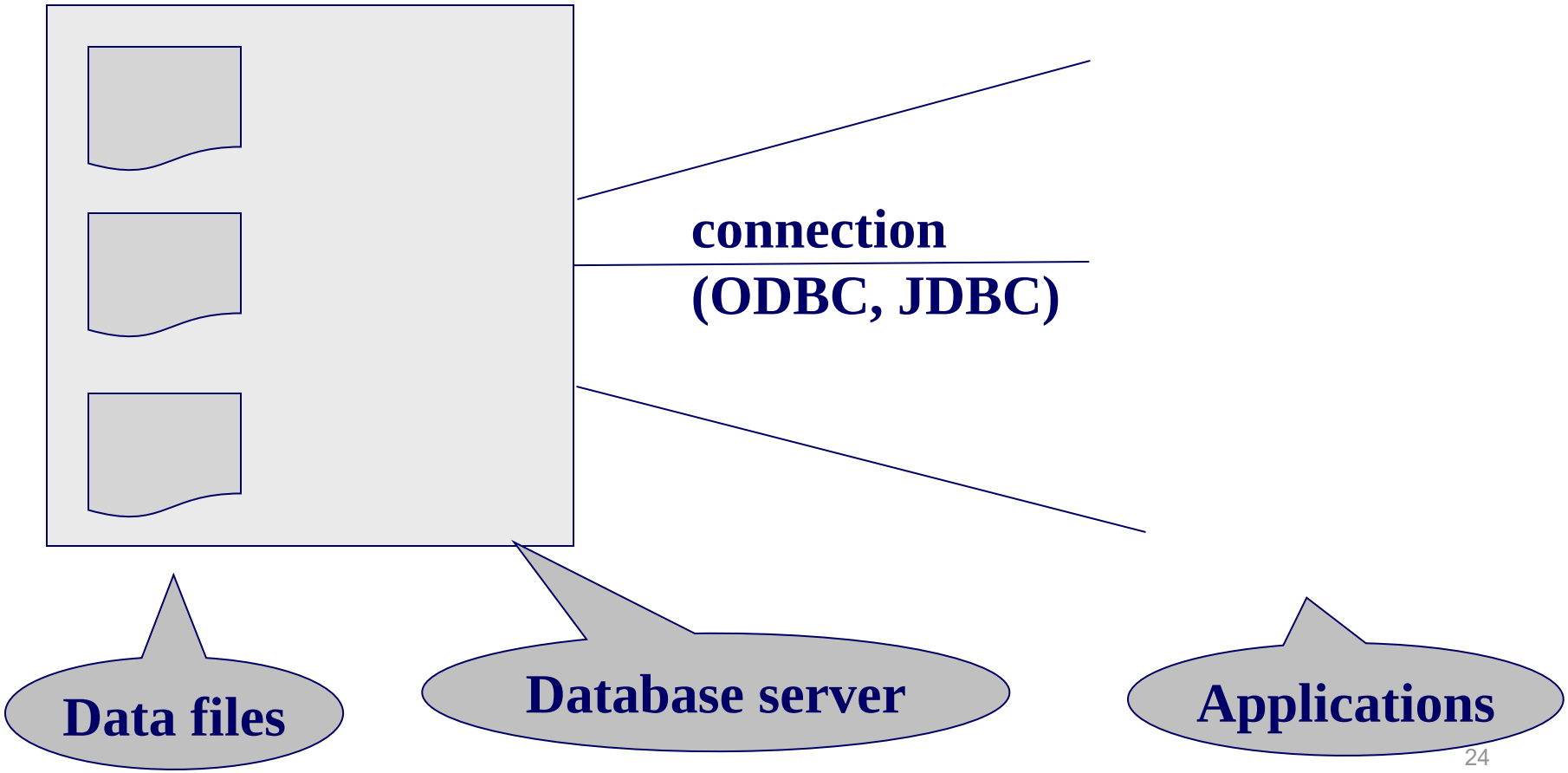
- Suppose while modifying the text file, the system crashes!

- A DBMS is able to guarantee 100% recovery from system crashes (to a consistent state).

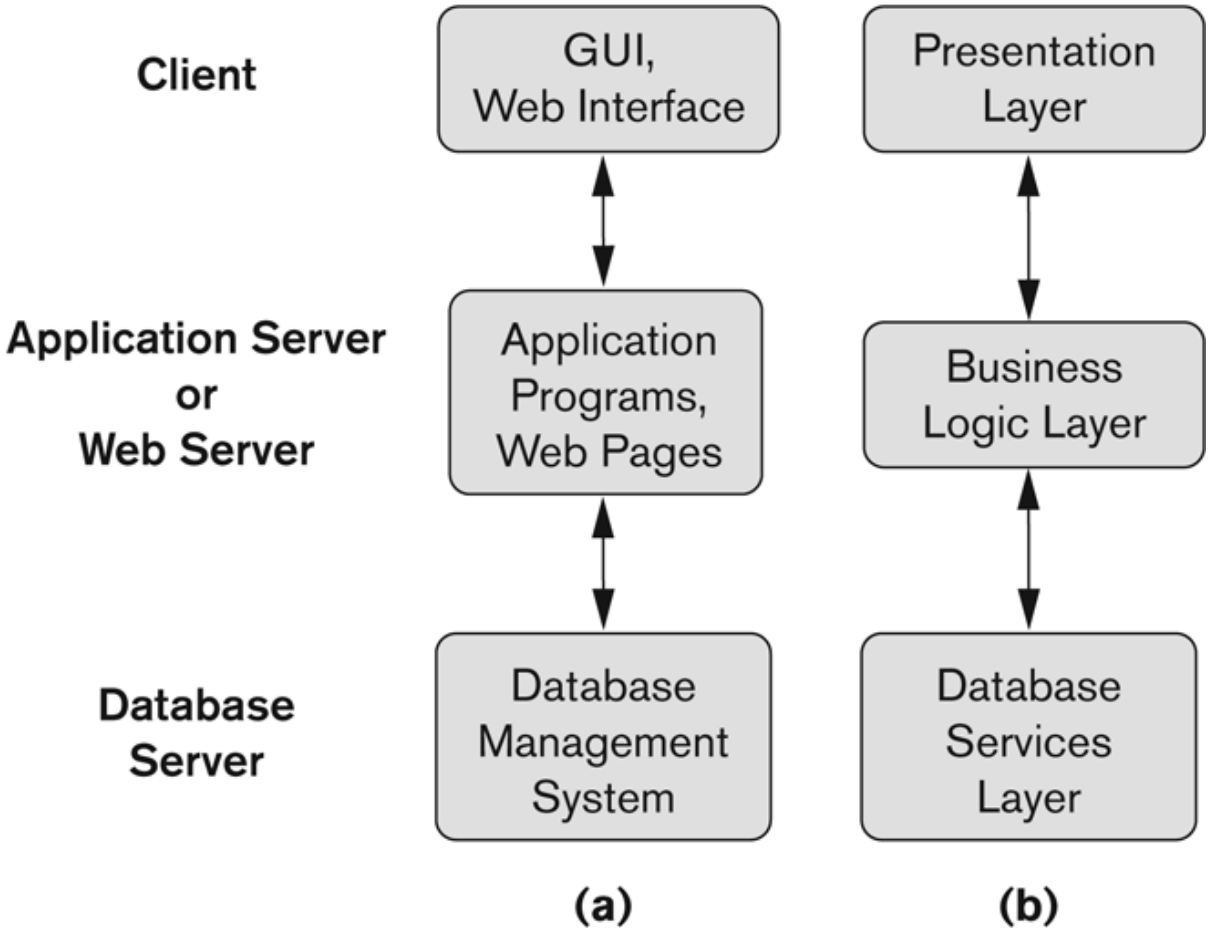


Building the Applications (2-tier)

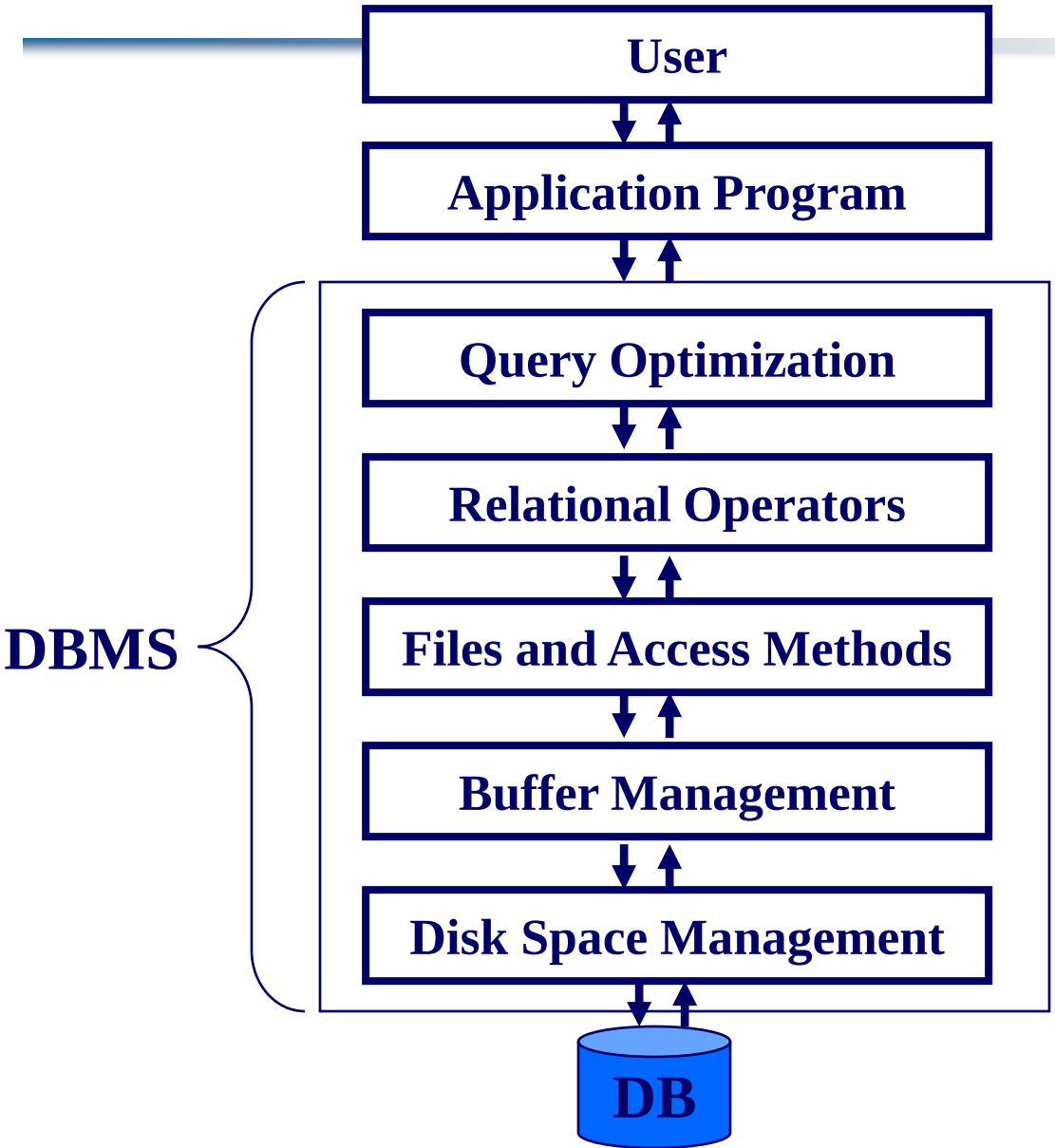
“Two tier database system”



Building the Applications (3-tier)



Control Abstraction



Each layer need not know (or care) how other layers are implemented

The Database Abstraction Provided by the DBMS

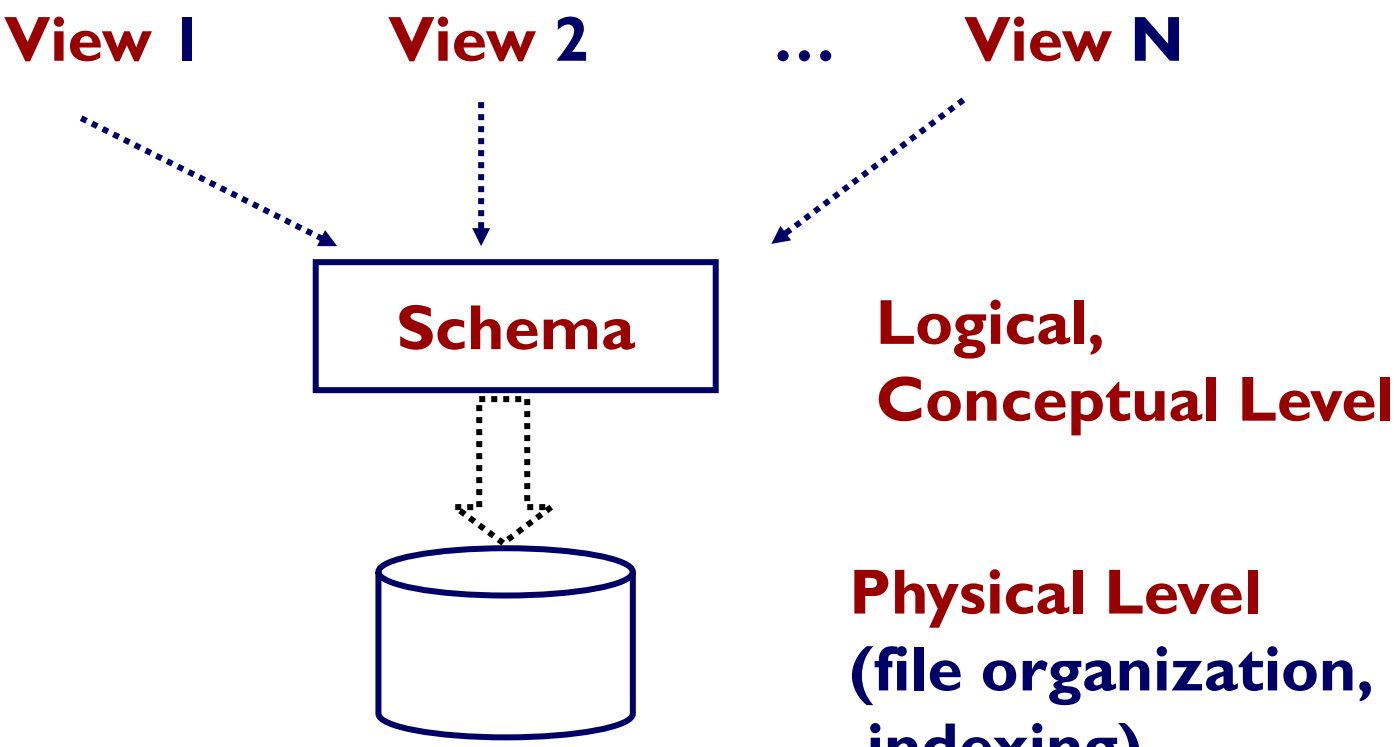
We think of databases at two levels:

- Logical structure:
  - What users/programmers see – program or query interface
- Physical structure:
  - Organization on disk, indices, etc.

The logical level is further split into:

- Overall database design (conceptual; seen by the DB designer)
- Views that various users get to see

The Three-level Architecture for Databases



Functionality of a DBMS

The programmer sees SQL, which has two components:

- Data Definition Language – DDL
  - Creating database tables
- Data Manipulation Language - DML
  - query language

Behind the scenes the DBMS has:

- Query engine
- Query optimizer
- Storage management
- Transaction Management (concurrency, recovery)

How the Programmer Sees the DBMS

- Start with DDL to *create tables*:

```
CREATE TABLE Students (
        Name CHAR(30)
        SSN CHAR(9) PRIMARY KEY NOT NULL,
        Category CHAR(20)
) . . .
```

- Continue with DML to *populate tables:*

```
INSERT INTO Students
VALUES('Charles', '123456789', 'undergraduate')
. . . .
```

How the Programmer Sees the DBMS

- Tables:

Students:

SSN	Name	Category
123-45-6789	Charles	undergrad
234-56-7890	Dan	grad
	…	…

Takes:

SSN	CID
123-45-6789	CSE444
123-45-6789	CSE541
234-56-7890	CSE142
	…

Courses:

CID	Name	Quarter
CSE444	Databases	fall
CSE541	Operating systems	winter

- Still implemented as files, but behind the scenes can be quite complex

"*data independence*" = separate *logical* view from *physical implementation*

Transactions

- Enroll “John Smith” in “COEN444”:

```
BEGIN TRANSACTION;

INSERT INTO Takes
   SELECT Students.SSN, Courses.CID
   FROM Students, Courses
   WHERE Students.name = ‘John Smith’ and
               Courses.name = ‘Databases’

-- More updates here....

IF everything-went-OK
     THEN COMMIT;
ELSE ROLLBACK
```

If system crashes, the transaction is still either committed or aborted

Transactions

- A *transaction* = sequence of statements that either all succeed, or all fail
- Transactions have the ACID properties:

A = atomicity

each transaction be "all or nothing": if one part of the transaction fails, the entire transaction fails

C = consistency

Any transaction will bring the database from one valid state to another

I = independence

ensures that the concurrent execution of transactions results in a system state that would be obtained if transactions were executed serially

D = durability

once a transaction has been committed, it will remain so, even in the event of power loss, crashes, or errors.

Queries

- Find all courses that “John” takes

```
SELECT  C.name
FROM    Students S, Takes T, Courses C
WHERE   S.name=“John” and
            S.ssn = T.ssn and T.cid = C.cid
```

- What happens behind the scene ?
  - Query processor figures out how to answer the query efficiently.

Data Independence

Logical data independence

Protects the user from changes in the logical structure of the data:

could reorganize the calendar “schema” without changing how we query it

Physical data independence

Protects the user from changes in the physical structure of data:

could add an index on who (or sort by when) without changing how the user would write the query, but the query would execute faster (query optimization)

Advantages of a DBMS

- Data Independence
  - Logical Data Independence

    Ability to change the logical (conceptual) schema without changing the External schema (User View)
  - Physical Data Independence

    Ability to change the physical schema without changing the logical schema

    Protection from changes in physical structure of data.
- Query expressiveness
- Reduced application development time.
- Concurrency and Crash Recovery
  - Schedule concurrent access to the data
- Security
  - Enforce access controls

Database Users

- End users (or DB application users)
- DB application programmers (more precisely, they are *DBMS* users)
  - E.g. webmasters
- *Database administrator (DBA)*
  - Designs logical /physical schemas
  - Handles security and authorization
  - Data availability, crash recovery
  - Database tuning as needs evolve

Must understand how a DBMS works!

Data Model

- Data Model:
  - Collection of concepts for describing data
- Schema
  - Description of a particular collection of data, using the a given data model.
- Relational model of data
  - Main concept: relation, basically a table with rows and columns.
  - Every relation has a schema, which describes the columns, or fields

ER Model Basics

- Entity:
  - A real world object or thing
- Attribute
  - Each entity has attributes
- Entity Set
  - Collection of similar entities
  - All entities in an entity set have the same set of attributes

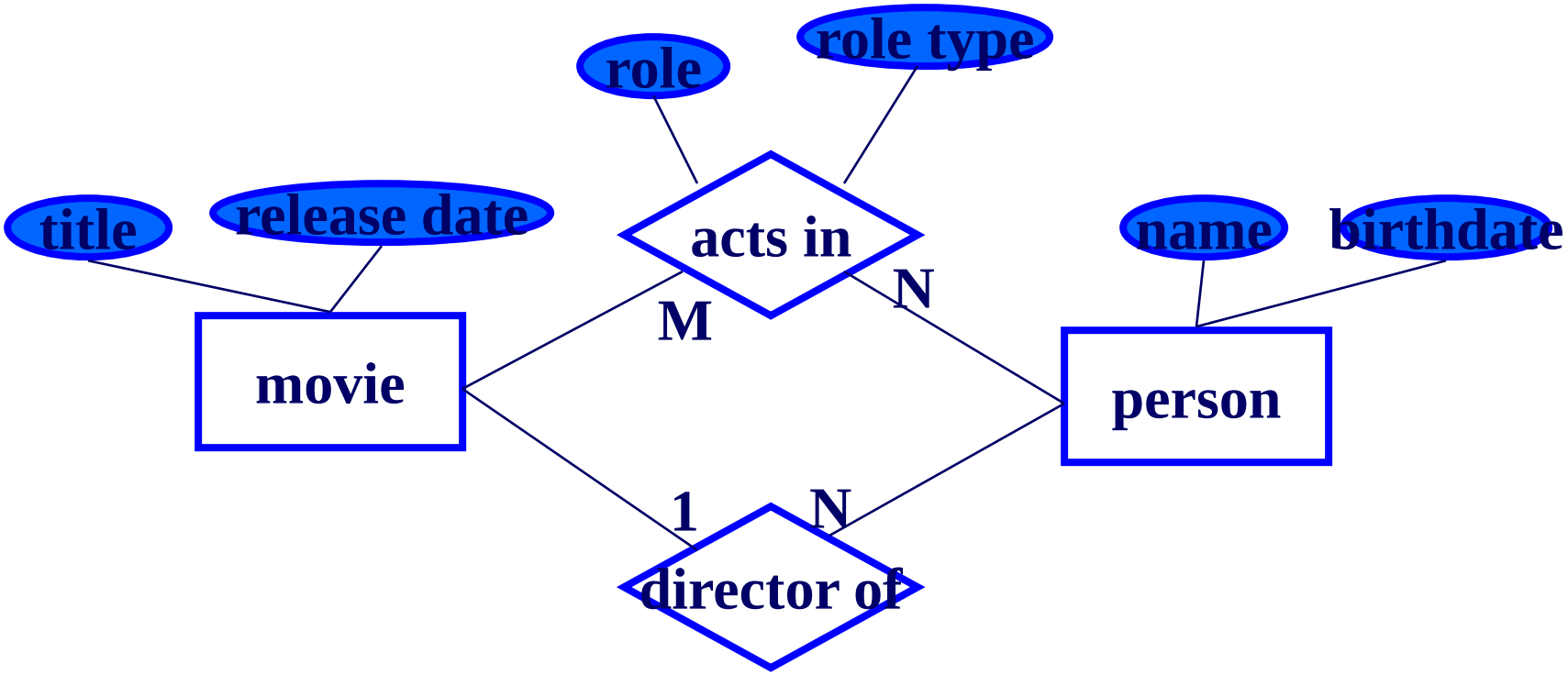
An entity can be uniquely identified thru its attributes

Overview of Database Design

- *Conceptual design*
  - Use *ER Model:* E- *Entities* and R-*Relationships*
  - Decide the *entities* and *relationships* in the enterprise.
  - Decide what information about these entities and relationships should we store in the database.
  - Decide the *integrity constraints* or *business rules.*
- *Implementation (logical design)*
  - Map an ER model into a relational schema.

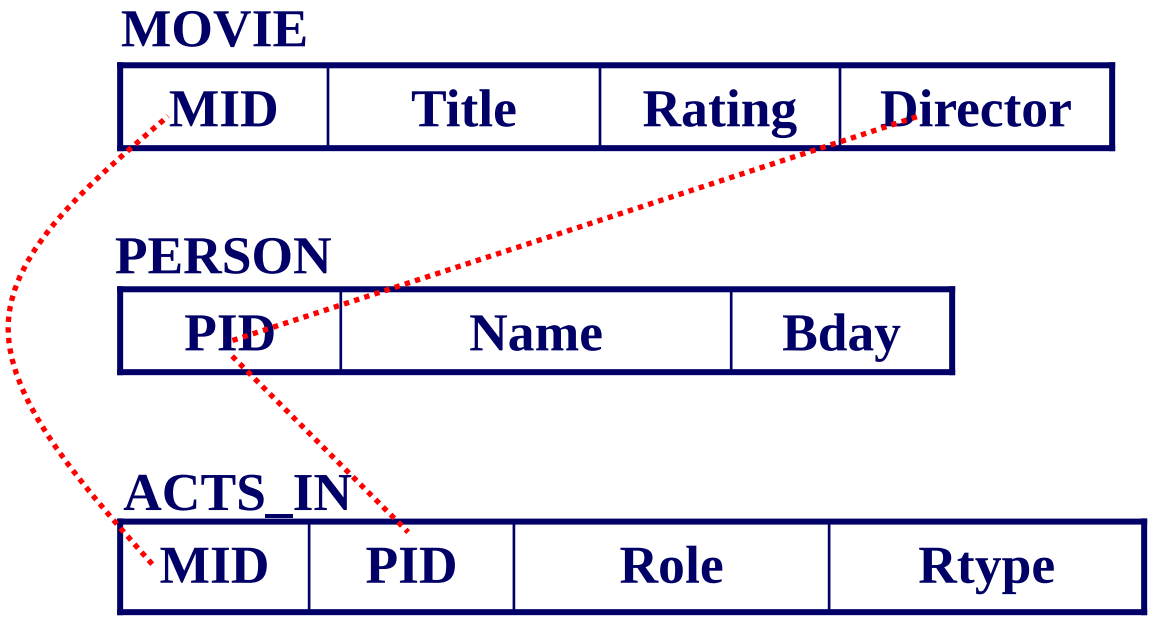
Building a DB: construct a conceptual model

- A conceptual model identifies entities and relationships



Building a DB: Define Relational *Schema*

- A schema describes DB using *data model* supported by DMBS (eg, *relational model)*
- RDBMS – DBMS that supports relational model



Building a DB: Populate DB

MOVIE

MID	Title	Rating	Director
1	The Big Lebowski	R	72
2	Star Wars	PG	29
...			

ACTS_IN

MID	PID	Role	Rtype
1	1	The Dude	STAR
2	2	Han Solo	CO_STAR
...			

PERSON

PID	Name	Bday
1	Jeff Daniels	12/4/49
2	Harrison Ford	7/13/42
...		

Set initial records of the DB

Querying The Database

- Most RDBMS allow users to query the database using SQL (structured query language)
- Example: get cast of “The Big Lebowski”

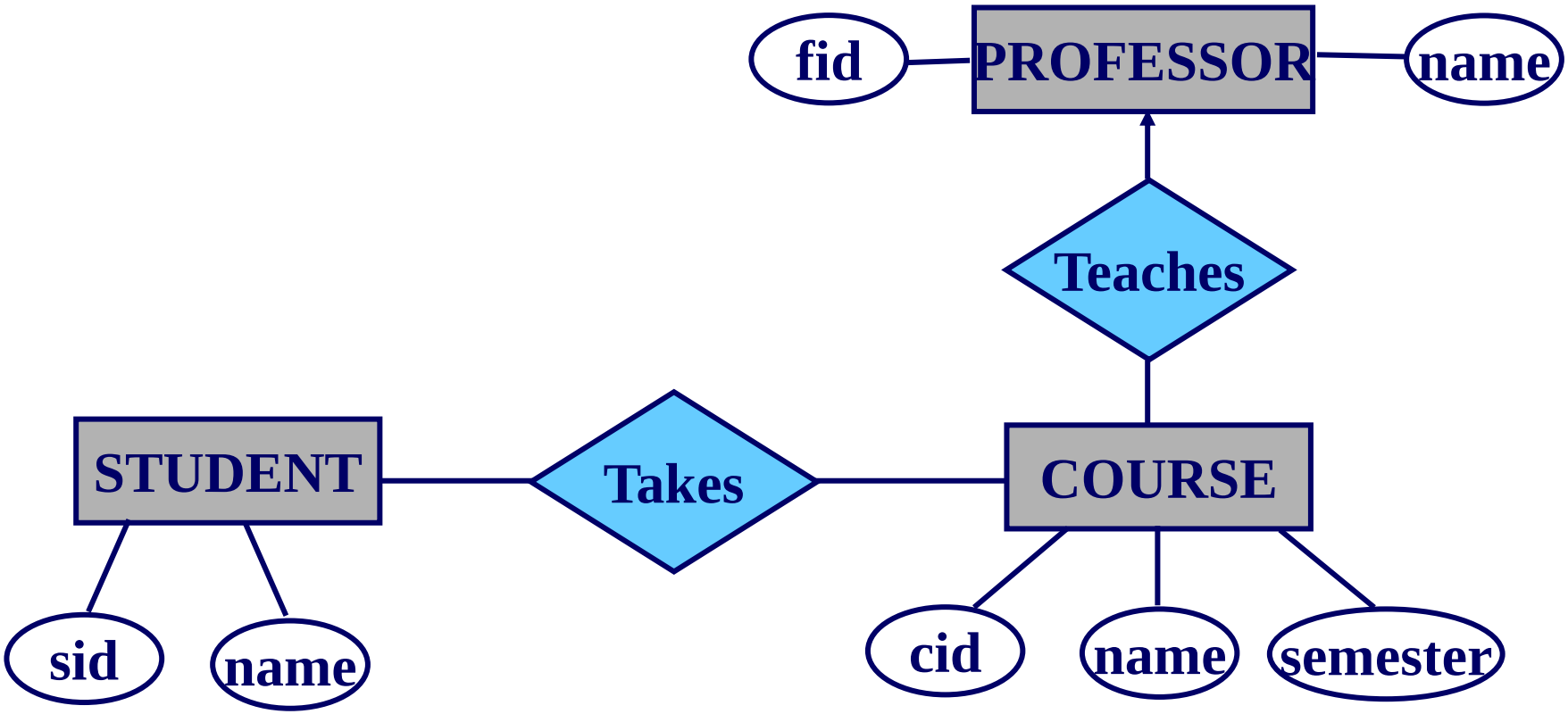
```
SELECT Name, Role, Rtype
FROM PERSON, ACTS_IN
WHERE MID = ‘1’ AND PERSON.PID == ACTS_IN.PID
```

Applications Use Queries in SQL

- Structured Query Language, often embedded (e.g., in Servlets, JSP, etc)
- Converted into a query plan that exploits properties; run over the data by the query optimizer and query execution engine

```
<html>
<body>
 <!– hypothetical Embedded SQL:
   SELECT Name, Role, Rtype
    FROM PERSON, ACTS_IN
    WHERE MID = ‘1’ AND
    PERSON.PID == ACTS_IN.PID
 -->
</body>
</html>
```

Another Example
Logical Model of a Database



Designing a Schema (Set of Relations)

STUDENT

sid	name
1	Jill
2	Bo
3	Maya

Takes

sid	cid
1	550-001
1	677-001
3	521-001

COURSE

cid	name	sem
550-001	DB	F11
677-001	Algo	F11
521-001	AI	S11

- Convert to tables + constraints
- Then need to do "physical" design: the layout on disk, indices, etc.

PROFESSOR

fid	name
1	Ives
2	Kannan
8	Ungar

Teaches

fid	cid
1	550-001
2	677-001
8	521-001

Database Systems

- The big commercial database vendors:
  - Oracle
  - IBM (with DB2)
  - Microsoft (SQL Server)
  - Sybase
- Some free database systems :
  - MySQL (acquired by Oracle..)
  - PostgreSQL

People who work with DBMSs

- Database Administrator DBA
  - Maintains databases, DBMS and related software
- Application Programmers
  - Software engineers (developers) that build software solutions for end users that access DBMS
- End Users
  - Example: bank teller uses “canned transactions”
- DBMS designers and implementers
  - Example: Oracle developers

New Trends in Databases

- Object-relational databases
- Main memory database systems
- XML
  - Relational databases with XML support
  - Native XML database systems
  - Lots of research on XML and databases
- Data integration
- Peer to peer, stream data management – still research
- BIG DATA
- NoSQL