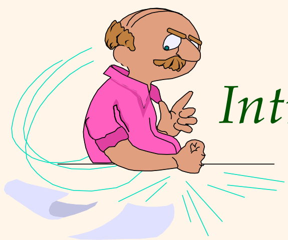
Introduction to Data Management



Lecture #2
Intro II & Data Models I

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Today's Topics

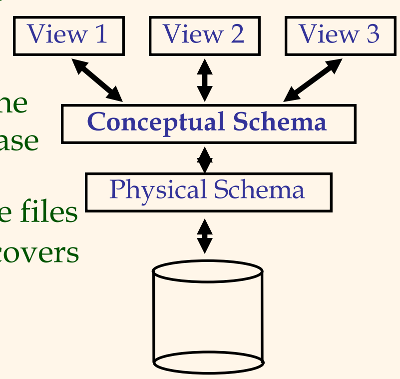
- The biggest class *ever* continues…! ☺
- Read (and live by!) the course wiki page:
  - http://www.ics.uci.edu/~cs122a/
  - Note the new dates for the Endterm and last two HW's (!)
- Also follow (and live by) the Piazza page:
  - https://piazza.com/uci/spring2019/cs122a/home
  - Everyone needs to get signed up! (290/420 at last glance…)
- The first HW assignment will become available at class time on Friday
  - We'll be supporting a hypothetical personal health logging application (kind of an ***IoT***-ish application) this term

Data Models

- A *data model* is a collection of concepts for describing data
- A *schema* is a description of a particular collection of data, using a given data model
- The *relational model* is (still) the most widely used data model today
  - *Relation* – basically a table with rows and (named) columns
  - *Schema* – describes the tables and their columns

Levels of Abstraction

- Many *views* of one *conceptual (logical) schema* and an underlying *physical schema*
  - Views describe how different users see the data.
  - Conceptual schema defines the logical structure of the database
  - Physical schema describes the files and indexes used under the covers



Example: University DB

- Conceptual schema:
  - *Students(sid: string, name: string, login: string, age: integer, gpa: real)*
  - *Courses(cid: string, cname: string, credits: integer)*
  - *Enrolled(sid: string, cid: string, grade: string)*
- Physical schema:
  - Relations stored as unordered files
  - Index on first and third columns of *Students*
- External schema (*a.k.a.* view):
  - *CourseInfo(cid: string, cname: string, enrollment: integer)*

Data Independence

- Applications are *insulated* (at multiple levels) from how data is actually structured and stored, thanks to schema layering and high-level queries
  - *Logical data independence*: Protection from changes in the *logical* structure of data
  - *Physical data independence*:   Protection from changes in the *physical* structure of data
- *One of the most important benefits of DBMS use!*
  - Allows *changes* to occur – *w/o application rewrites!*

University DB Example (cont.)

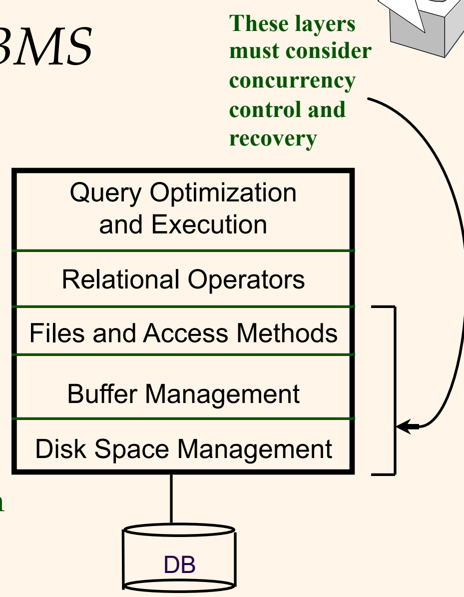
- User query (in SQL, against the external schema):
  - *SELECT c.cid, c.enrollment*
    FROM CourseInfo c
    WHERE c.cname = 'Computer Game Design'
- Equivalent query (against the conceptual schema):
  - *SELECT e.cid, count(e.*)*
    FROM Enrolled e, Courses c
    WHERE e.cid = c.cid AND c.cname = 'Computer Game Design'
    GROUP BY c.cid
- Under the hood (against the physical schema)
  - Access *Courses* – use index on *cname* to find associated *cid*
  - Access *Enrolled* – use index on *cid* to count the enrollments

Concurrency and Recovery

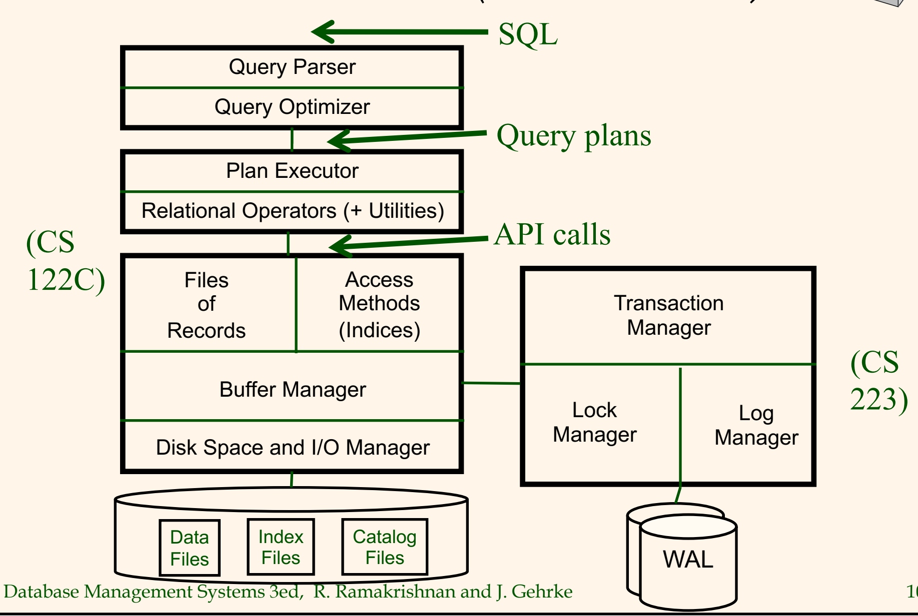
- *Concurrent execution* of user programs is essential to achieve good DBMS performance.
  - Disk accesses are frequent and slow, so it's important to keep the CPUs busy by serving multiple users' programs concurrently.
  - Interleaving multiple programs' actions can lead to inconsistency: e.g., a bank transfer while a customer's assets are being totalled.
- *Errors or crashes* may occur during, or soon after, the execution of users' programs.
  - This could lead to undesirable partial results or to lost results.
- DBMS answer: Users/programmers can pretend that they're using a reliable, single-user system!

Structure of a DBMS

- A typical DBMS has a layered architecture.
- The figure does not show the concurrency control and recovery components (CS 223).
- This is one of several possible architectures; each system has its own variations.



DBMS Structure (More Detail)



Components' Roles

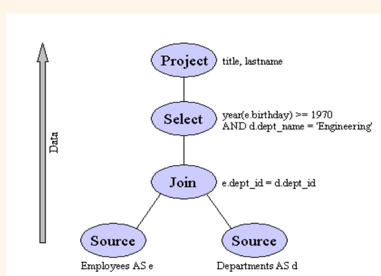
```
SELECT e.title, e.lastname
FROM Employees e, Departments d
WHERE e.dept_id = d.dept_id AND
        year (e.birthday >= 1970) AND
        d.dept_name = 'Engineering'
```

- Query Parser
  - Parse and analyze *SQL query*
  - Makes sure the query is valid and talking about tables, etc., that indeed exist
- Query optimizer (usually has 2 steps)
  - *Rewrite* the query logically
  - Perform cost-based *optimization*
  - Goal is finding a "good" query plan considering
    - Available access paths (files & indexes)
    - Data statistics (if known)
    - Costs of the various relational operations

(Cost differences can be orders of magnitude!!!)

Components' Roles (continued)

- Plan Executor + Relational Operators
  - Runtime side of query processing
  - Query plan is a tree of relational operators (drawn from the ***relational algebra***, which you will learn all about in this class)



Components' Roles (continued)

- Files of Records
  - DBMSs have ***record*** based APIs under the hood
    - Record = set of fields
    - Fields are typed
    - Records reside on pages of files
- Access Methods
  - Index structures for lookups based on field values
  - We'll look in more depth at ***B+ tree*** indexes in this class (the most commonly used indexes for both commercial and open source DBMSs)

Components' Roles (continued)

- Buffer Manager
  - The DBMS answer to *main memory* management!
  - All disk page accesses go through the buffer pool
  - Buffer manager caches pages from files and indices
- Disk Space and I/O Managers
  - Manage space on *disk* (pages)
  - Also manage I/O (sync, async, prefetch, …)
  - Remember: database data is *persistent (!)*

Components' Roles (continued)

- System Catalog (or "Metadata")
  - Info about tables (name, columns, column types, …);
  - Data statistics (e.g., counts, value distributions, …)
  - Info about indexes (tables, index kinds, …)
  - And so on! (Views, security, …)
- Transaction Management
  - ACID (Atomicity, Consistency, Isolation, Durability)
  - Lock Manager for Consistency + Isolation
  - Log Manager for Atomicity + Durability

Miscellany: Some Terminology

- Data Definition Language (DDL)
  - Used to express views + logical schemas (using a syntactic form of a a data model, e.g., relational)
- Data Manipulation Language (DML)
  - Used to access and update the data in the database (again in terms of a data model, e.g., relational)
- Query Language (QL)
  - Synonym for DML or its retrieval (i.e., data access or query) sublanguage

Miscellany (Cont'd.): Key Players

- Database Administrator (DBA)
  - The "super user" for a database or a DBMS
  - Deals with physical DB design, parameter tuning, performance monitoring, backup/restore, user and group authorization management
- Application Developer
  - Builds data-centric applications (take CS122b!)
  - Involved with logical DB design, queries, and DB application tools (e.g., JDBC, ORM, …)
- Data Analyst or End User
  - Non-expert who uses tools to interact w/the data

A Brief History of Databases

- Pre-relational era: 1960's, early 1970's
- Codd's seminal paper: 1970
- Basic RDBMS R&D: 1970-80 (System R, Ingres)
- RDBMS improvements: 1980-85
- Relational goes mainstream: 1985-90
- Distributed DBMS research: 1980-90
- Parallel DBMS research: 1985-95
- Extensible DBMS research: 1985-95
- OLAP and warehouse research: 1990-2000
- Stream DB and XML DB research: 2000-2010
- "Big Data" R&D (also including "NoSQL"): 2005-present

Introductory Recap

- DBMS is used to maintain & query large datasets.
- Benefits include recovery from system crashes, concurrent access, quick application development, data integrity and security.
- Levels of abstraction give data independence.
- A DBMS typically has a layered architecture.
- DBAs (and friends) hold responsible jobs and they are also well-paid! (☺)
- Data-related *R&D* is one of the broadest, most exciting areas in CS.

So Now What?

- Time to dive into the first tech topic:
  - ***Logical DB design*** (ER model)
- Read the first two chapters of the book
  - Intro and ER – see the syllabus on the wiki
- Immediate to-do's for you are:
  - Again, be sure that you're signed up on Piazza
  - And, stockpile sleep – no homework ***yet*** (☺)
- ***Let's switch gears to database design…***

Overview of Database Design

- *Conceptual design*: *(ER Model used at this stage.)*
  - What are the *entities* and *relationships* in the enterprise?
  - What information about these entities and relationships should we store in the database?
  - What are the *integrity constraints* or *business rules* that hold?
  - A database schema in the ER Model can be represented pictorially (using an *ER diagram*).
  - Can map an ER diagram into a relational schema (manually or using a design tool's automation).

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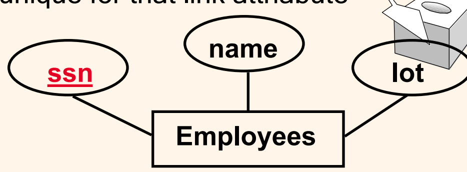
ER Model Basics



- *Entity:* Real-world object, distinguishable from all other objects. An entity is described (in DB-land) using a set of *attributes*.
- *Entity Set*: A collection of similar entities. E.g., all employees.
  - All entities in an entity set have the ***same*** set of attributes. (Until we get to ISA hierarchies…)
  - Each entity set has a *key* (a unique identifier); this can be either one attribute (an "atomic" key) or several attributes (called a "composite" key)
  - Each attribute has a *domain* (similar to a data type).

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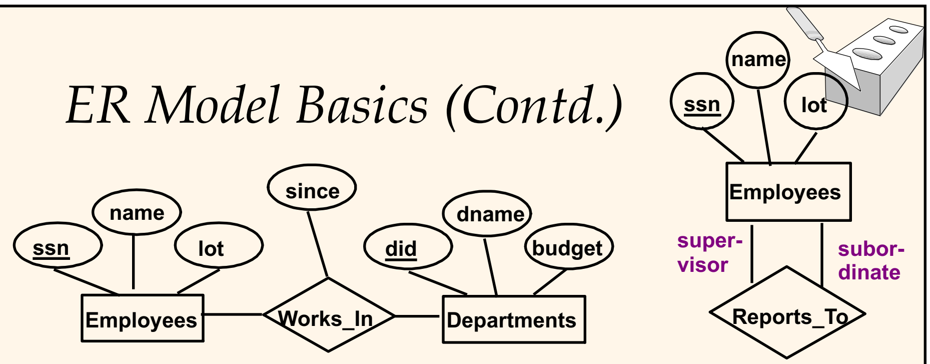
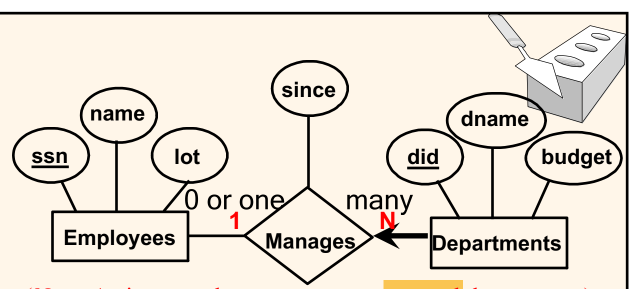
ER Model Basics (Contd.)



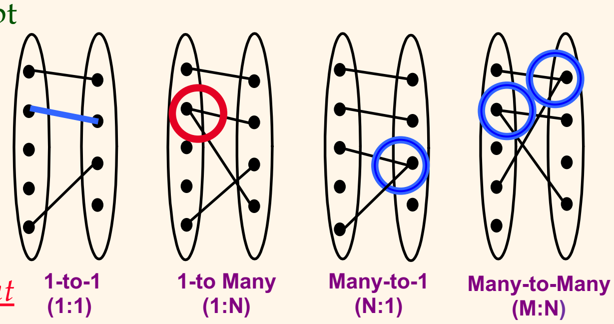
- *Relationship*: Association among two or more entities. E.g., Santa Claus works in the Toy department.
- *Relationship Set*: Collection of similar relationships.
  - An n-ary relationship set R relates n entity sets E1 ... En; each relationship in R involves entities e1:E1, ..., en:En
    - One entity set can participate in different relationship sets – or in different "roles" in the same set.

Cardinality Constraints



(*Note:* A given employee can manage several departments)

- Consider Works In: An employee can work in many departments; a dept can have many employees.
- In contrast, each dept has at most one manager, according to the *cardinality constraint* on Manages above.



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