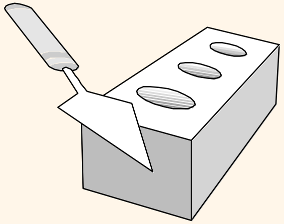
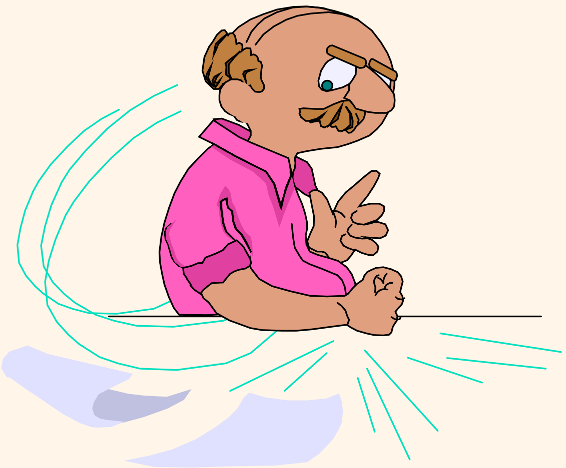


Database Management Systems (DBMS)

Chapter 1



Instructor:

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Welcome to CSCI 4707

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Welcome to CSCI 4707

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Grading Policy

- Final Exam: 30% (Inclusive)
- Two Midterm Exams: 25% (12.5% each)
- Four Homeworks: 10% (2.5% each)
- Four Labs: 35%
  - Lab # 1 (3%): Individual
  - Lab # 2 (7%): Individual
  - Lab # 3 (13%): (Group of 2)
  - Lab # 4 (12%): (Group of 2)
- Every one-day late submission reduces 10% of the grade.
- No more than three-day late submission is allowed for each lab/homework, no more than 6 late submission days for all labs/homeowrks.

Welcome to CSCI 4707

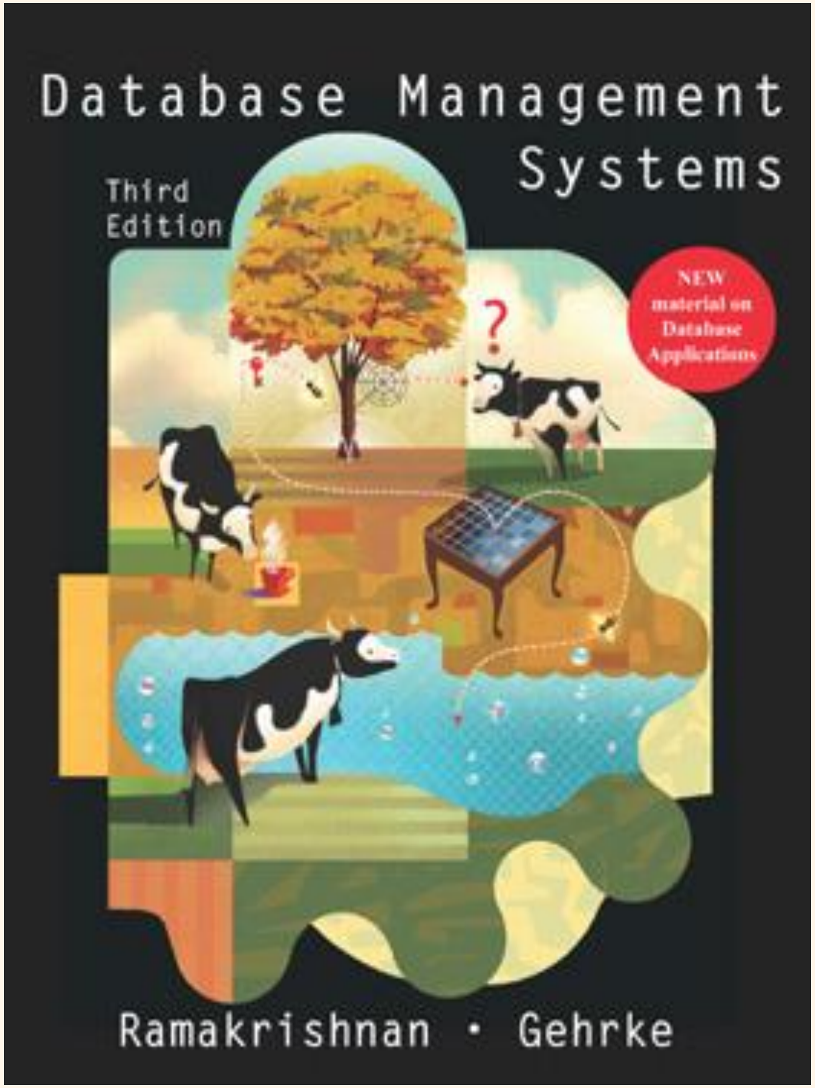
- ❖ **Text Book:**

  Database Management Systems, 3e (ISBN: 0-07-246563-8)

  Raghu Ramakrishnan and Johannes Gehrke

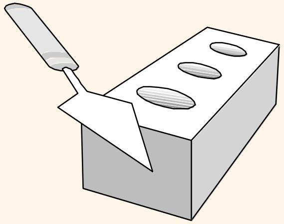
  Book website: http://www.cs.wisc.edu/~dbbook/

  - Chapters: 1-5, 8, 9, 12-20



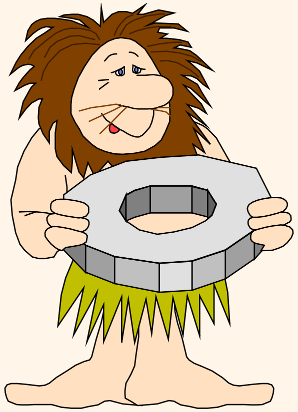
- ❖ **Class web page:**
  - http://www-users.cselabs.umn.edu/classes/Fall-2015/csci4707/index.php
  - Tentative scheduling is in the course web site
  - Stay tuned for announcements, labs, homeworks, and grades

What we will study in the Course



- PART 1: *Outside* the Database Engine as a *User*
  - How to do conceptual database design (Chapter 2)
  - How to do a logical database design (Chapter 3)
  - How to query the database (Chapters 4, 5)
- PART 2: *Inside* the Database Engine
  - Storage and indexing modules (Chapters 8-10)
  - Query processing & optimization (Chapters 12-15)
  - Transaction Processing (Chapters 16-18)
- PART 3: *Outside* the Database Engine as a *DBA*
  - How to refine your schema design (Chapter 19)
  - How to tune the database design (Chapter 20)

What Is a DBMS?

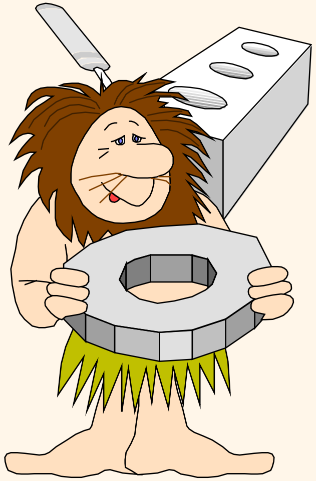


- How do you store your friend's phone numbers:

Name	Home	Cell	Address	Email

- Designing, storing, and managing such "simple" tables is the core of DBMS

What Is a DBMS?



- A VERY LARGE, integrated collection of data.
- Models real-world:
  - Entities (e.g., universities, departments, students, courses)
  - Relationships (e.g., Students are taking courses)
- A *Database Management System (DBMS)* is a software package designed to store and manage data.

History of DBMS

- Early 60's
  - First general-purpose DBMS by Charles Bachman at General Electric (First recipient of ACM Turing Award in 1973)
- Late 60's
  - Hierarchical data model developed at IBM
  - The SABRE system for airline reservation is jointly developed by American Airlines and IBM where several people can access the same data through a network

History of DBMS

- 70's
  - The relational data model is proposed by Edgar Codd at IBM (ACM Turing Award at 1981)
  - Two main prototypes for relational database management systems are developed. Ingres at UCB and System R at IBM (Mike Stonebraker received the ACM Turing Award at 2014)
  - Peter Chen (MIT) proposed the entity-relationship model
- 80's
  - SQL query language is developed (part of System R)
  - The concept of read/write transactions is developed to allow concurrent execution of database operations (Jim Gray received the ACM Turing Award at 1998)
  - Commercial databases are in the market (DB2, Oracle, Informix)

History of DBMS

- 90's - present
  - DBMSs are well-established in industry and academia
  - New database applications:
    - Data warehousing
    - Multimedia databases
    - Spatial/Spatio-temporal databases
    - Data mining
    - Scientific database
    - Bioinformatics
    - Digital libraries
    - Web-databases

Files vs. DBMS

- Special code for different queries
- Must protect data from inconsistency due to multiple concurrent users
- Crash recovery
- Security and access control

Why Use a DBMS?

- Data independence
  - Applications are independent from data representation
- Efficient data access
  - Through indexing and query optimization techniques
- Data integrity and security
  - DBMS enforce integrity constraints and access control
- Concurrent access
  - Multiples users are allowed to use the same tables
- Crash recovery
  - DBMS protects the user from the system failure
- Reduced application development time
  - DBMS supports functions that are common to many applications

Why Study Databases??

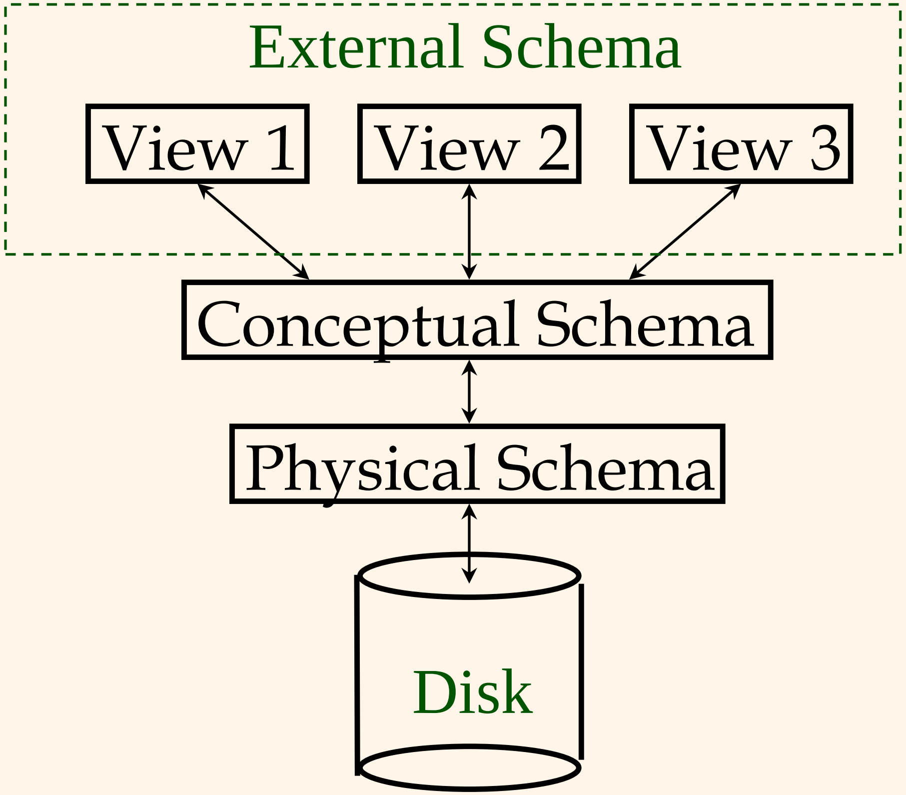
- Shift from *computation* to *information*
  - at the "low end": scramble to webspace (a mess!)
  - at the "high end": scientific applications
- Datasets increasing in diversity and volume.
  - Digital libraries, interactive video, Human Genome project, Earth Observation project
  - ... need for DBMS exploding
- Good job market as a DBA, system analyst,
- 3-credit course(s)

Concepts of Data Modeling

- A ***data model*** is a collection of concepts for describing data.
- A ***schema*** is a description of a particular collection of data, using the a given data model.
- The ***relational model of data*** is the most widely used model today.
  - Main concept: ***relation***, basically a table with rows and columns.
  - Every relation has a ***schema***, which describes the columns, or fields.

Levels of Abstraction

- Many *views*, single *conceptual schema* and *physical schema*.
  - Views (External schema) describe how users see the data.
  - Conceptual schema defines logical structure
  - Physical schema describes the files and indexes used.



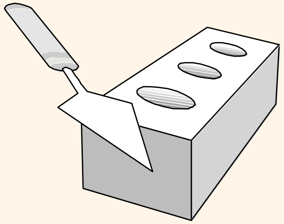
Example: University Database

- 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 column of Students.
- External Schema (View):
  - *Course_info(cid:string,enrollment:integer)*

Data Independence *

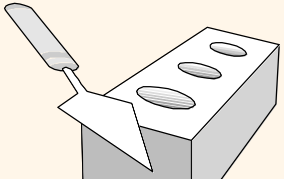
- Applications insulated from how data is structured and stored.
- *Logical data independence*: Protection from changes in *logical* structure of data.
- *Physical data independence*: Protection from changes in *physical* structure of data.

* *One of the most important benefits of using a DBMS!*



Concurrency Control

- Concurrent execution of user programs is essential for good DBMS performance.
  - Because disk accesses are frequent, and relatively slow, it is important to keep the CPU working on several user programs concurrently.
- Interleaving actions of different user programs can lead to inconsistency: e.g., check is cleared while account balance is being computed.
- DBMS ensures such problems don't arise: users can pretend they are using a single-user system.



Transaction: An Execution of a DB Program

- Key concept is *transaction,* which is an *atomic* sequence of database actions (reads/writes).
- Each transaction, executed completely, must leave the DB in a *consistent state* if DB is consistent when the transaction begins.
  - Users can specify some simple *integrity constraints* on the data, and the DBMS will enforce these constraints.
  - Beyond this, the DBMS does not really understand the semantics of the data. (e.g., it does not understand how the interest on a bank account is computed).
  - Thus, ensuring that a transaction (run alone) preserves consistency is ultimately the user's responsibility!

Example

- Consider two transactions (*Xacts*):

```
T1:    BEGIN   A=A+100,    B=B-100    END
T2:    BEGIN   A=1.06*A,   B=1.06*B   END
```

- Intuitively, the first transaction is transferring \$100 from B's account to A's account. The second is crediting both accounts with a 6% interest payment.
- There is no guarantee that T1 will execute before T2 or vice-versa, if both are submitted together. However, the net effect *must* be equivalent to these two transactions running serially in some order.

Example (Contd.)

- Consider a possible interleaving (*schedule*):

```
T1:    A=A+100,                   B=B-100
T2:              A=1.06*A,                  B=1.06*B
```

- This is OK. But what about:

```
T1:    A=A+100,                             B=B-100
T2:              A=1.06*A, B=1.06*B
```

- The DBMS's view of the second schedule:

```
T1:    R(A), W(A),                                 R(B), W(B)
T2:                  R(A), W(A), R(B), W(B)
```

Scheduling Concurrent Transactions

- DBMS ensures that execution of {T1, ... , Tn} is equivalent to some *serial* execution T1' ... Tn'.
  - Before reading/writing an object, a transaction requests a lock on the object, and waits till the DBMS gives it the lock. All locks are released at the end of the transaction. (Strict 2PL locking protocol.)
  - Idea: If an action of Ti (say, writing X) affects Tj (which perhaps reads X), one of them, say Ti, will obtain the lock on X first and Tj is forced to wait until Ti completes; this effectively orders the transactions.
  - What if Tj already has a lock on Y and Ti later requests a lock on Y? (Deadlock!) Ti or Tj is aborted and restarted!

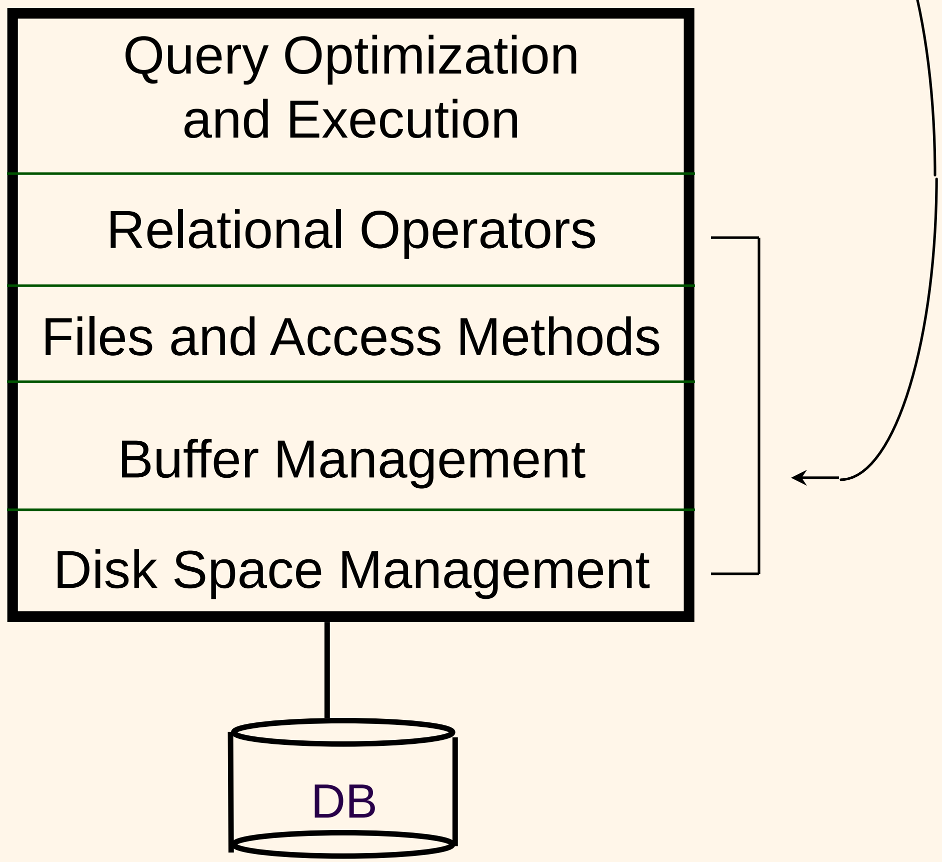
Ensuring Atomicity

- DBMS ensures *atomicity* (all-or-nothing property) even if system crashes in the middle of a transaction.
- Idea: Keep a *log* (history) of all actions carried out by the DBMS while executing a set of transactions:
  - Before a change is made to the database, the corresponding log entry is forced to a safe location.
  - After a crash, the effects of partially executed transactions are *undone* using the log.

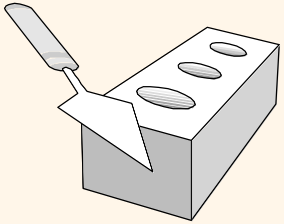
Structure of a DBMS

These layers must consider concurrency control and recovery

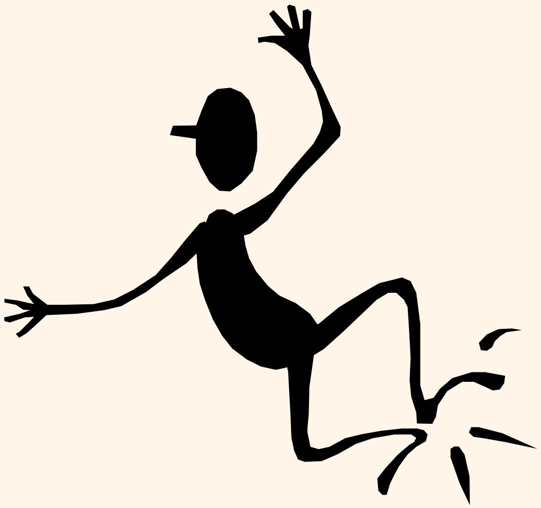
- A typical DBMS has a layered architecture.
- The figure does not show the concurrency control and recovery components.
- This is one of several possible architectures; each system has its own variations.



Databases make these folks happy ...



- End users
- DBMS vendors
- DB application programmers
- *Database administrator (DBA)*
  - Designs logical /physical schemas
  - Handles security and authorization
  - Data availability, crash recovery
  - Database tuning as needs evolve

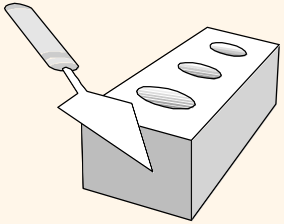


Steps for Designing a Database

1. Requirement analysis
   - An informal discussion with the customers
   - Understand what are the requirements, how different entities relate to each other, what are the frequent operations to be performed
2. Conceptual Database Design
   - Develop a high-level description of the data
   - Develop an ER (entity-relationship) model that capture the semantics of the data
3. Logical Database Design
   - Convert the ER model into a (relational) database schema

Steps for Designing a Database (Cont.)

4. Scheme Refinement
   - Identify potential problems in your schema design
   - This process can be guided by some elegant and powerful theory
5. Physical Database Design
   - Study the expected workload of the system
   - Tune the performance by building indexes and clustering tables
6. Application and Security Design
   - Identify which parts of the database are accessible to whom



Summary

- DBMS 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 hold responsible jobs and are well-paid!
- DBMS R&D is one of the broadest, most exciting areas in CS.