Database Systems
(資料庫系統)

9/16/2009

Lecture #1

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Course Goals

- First course in database systems.
- Learning objective
  - Use a relational database
  - Build a relational database

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Topics

- Fundamentals
  - ER (Entity-Relationship) Model
  - SQL (Structured Query Language)
- Storage and indexing
  - Disks & Files
  - Tree-structure indexing
  - Hash-based indexing
- Query evaluation
  - External sorting
  - Evaluating relational operators
- Transaction management:
  - Concurrency control
  - Crash recovery
- Other Topics

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Prerequisite

- Data structure and algorithms
- English skill
  - Taught in English & Chinese
  - If I speak English too fast, please tell me to slow down.
  - You can ask questions in English or Chinese.

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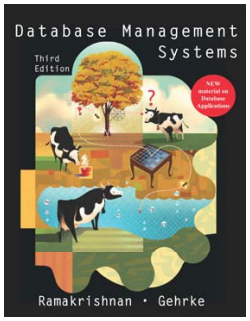
Textbook

- Required textbook: "Database Management Systems, Third Edition", by Ramakrishnan and Gehrke.
- The textbook is available from 新月 and (and perhaps other) bookstores.



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General Comments on Textbook

- Widely used among U.S. Universities 3~4 years ago.
- Bad
  - Ambiguous writing, inconsistent wording
  - "More like an experience report from researchers rather than introductory textbooks for beginners"

Ask me & TAs for clarifications

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Course Format

- 7 Assignments
  - Written (1), SQL(1), and Programming assignments (5)
- Midterm Exam
  - Fixed date: Nov 11, 2009 (Wed) in class
  - Offer once only!
- Final Exam
  - Fixed date: Jan 13, 2010 (Wed) during class time
  - Offer once only!

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Grading Breakdown (Tentative)

- Tentative means that it may be changed later.
  - 7 Assignments (30% of Grade)
  - Midterm Exam (35% of Grade)
  - Final Exam (35% of Grade)

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Teaching Staff

- Winston Hsu (徐宏民)
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  - Email: winston (at) csie.ntu.edu.tw
- Instructor: 朱浩華 "Hao"
  - Room 518 or by appointment
  - Email: hchu (at) csie.ntu.edu.tw
- TAs
  - Kerry Chang, Room 219, email: b94007 (at) csie ntu edu tw
  - Ming-Kuang Tsai (蔡旻光), email: mingkuang.tsai (at) gmail com
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Means of Communications

- Course homepage
  - http://mll.csie.ntu.edu.tw/course/database_f09/index.php
- BBS
  - ptt.cc, under "CSIE_DBMS" board
  - Post your questions on BBS.
  - Read posted messages before posting new questions.
  - No SPAM.
  - TAs respond to your questions as quickly as possible.
- Send email to TAs or me.
- Come to office hours

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Lecture Notes

- Available on the course homepage before each lecture
  - Complements, not replacement of attending lecture and reading textbook.

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Any Question(s) on Administrative Things?

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Introduce an interesting project in Ubiquitous Computing

(Won't be Tested)

How many students were in my OS course (last year)?

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Topobo (MIT media lab)

- Redefine programming
  - Create a program without "writing a program".

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Chapter 1:
Overview of Database Systems

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Outline

- Why do we need a DBMS (Database Management System)?
- What can a DBMS do for an application?
- Why study database systems?
- Data Models: Overview of a Relational Model
- Levels of Abstraction in a DBMS
- Sample Queries in DBMS
- Transaction Management Overview
- Structure of a DBMS

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Why DBMS?

- Suppose that you want to build an university database. It must store the following information:
  - Entities: Students, Professors, Classes, Classrooms
  - Relationships: Who teaches what? Who teaches where? Who teaches whom?

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What can DBMS do for applications?

- Store huge amount of data (e.g., TB+) over a long period of time
- Allow apps to query and update data
  - Query: what is Mary's grade in the "Operating System" course?
  - Update: enroll Mary in the "Database" course
- Protect from unauthorized access.
  - Students cannot change their course grades.
- Protect from system crashes
  - When some system components fail (hard drive, network, etc.), database can be restored to a good state.

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More on what can DBMS do for applications?

- Protect from incorrect inputs
  - Mary has registered for 100 courses
- Support concurrent access from multiple users
  - 1000 students using the registration system at the same time
- Allow administrators to easily change data schema
  - At a later time, add TA info to courses.
- Efficient database operations
  - Search for students with 5 highest GPAs

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Alternative to Using a DBMS

- Store data as files in operating systems.
- Applications have to deal with the following issues:
  - 32-bit addressing (5GB) is insufficient to address 100GB+ data file
  - Write special code to support different queries
  - Write special code to protect data from concurrent access
  - Write special code to protect against system crashes
  - Optimize applications for efficient access and query
  - May often rewrite applications
- Easier to buy a DBMS to handle these issues

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Database Management System (DBMS)

- DBMS is software to store and manage data, so applications don't have to worry about them.
- What can a DBMS do for applications?
  - Can you think of them?

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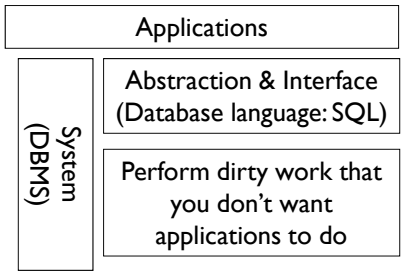
What can a DBMS do for applications?

- Define data: Data Definition Language (DDL)
- Access and operate on data: Data Manipulation Language (DML)
  - Query language
- Storage management
- Transaction Management
  - Concurrency control
  - Crash recovery
- Provide good security, efficiency, and scalability



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Why Study Database Systems?

- They are everywhere.
  - Online stores, real stores
  - Banks, credit card companies
  - Passport control
  - Police (criminal records)
  - Airlines and hotels (reservations)
- DBMS vendors & products
  - Oracle, Microsoft (Access and SQL server), IBM (DB2), Sybase, …

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Data Models

- A data model is a collection of concepts for describing data.
  - Entity-relation (ER) model
  - Relational model (main focus of this course)
- A schema is a description of data.
- The relational model is the most widely used data model.
  - A relation is basically a table with rows and columns of records.
  - Every relation has a schema, which describes the columns, or fields.

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Relational Model

- The entire table shows an instance of the Students relation.
- The Students schema is the column heads
  - Students(Sid: String, Name: String, Login: String, age: Integer,…)

sid	name	email	age	gpa
53666	Jones	Jones@cs	18	3.4
53688	Smith	Smith@ee	18	3.2
53650	Joe	Joe@cs	19	2.5

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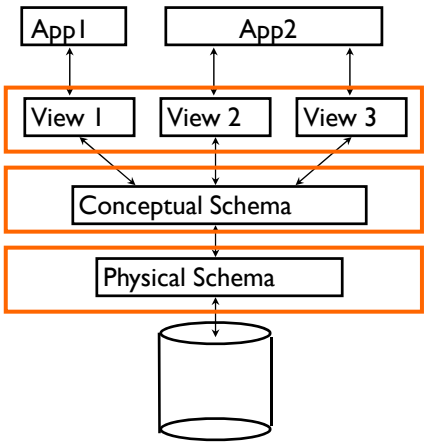
Levels of Abstractions in DBMS

- Many views, one conceptual schema and one physical schema.
  - Conceptual schema defines logical structure
    - Relation tables
  - Physical schema describes the file and indexing used
    - Sorted file with B+ tree index
  - Views describe how applications (users) see the data
    - Relation tables but not store explicitly



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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.
- View (External Schema):
  - Course_info(cid:string, enrollment:integer)
  - Why?

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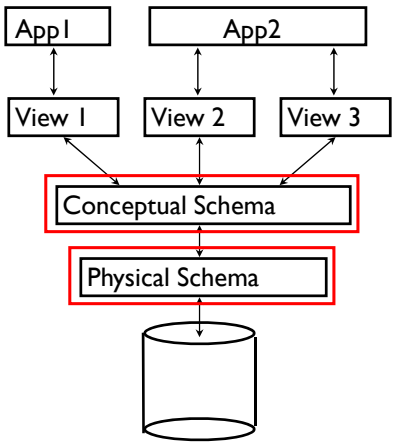
Data Independence

- Three levels of abstraction provides data independence.
  - Changes in one layer only affect one upper layer.
  - E.g., applications are not affected by changes in conceptual & physical schema.



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Queries in DBMS

- Sample queries on university database:
  - What is the name of the student with student ID 123456?
- The key benefits of using a relational database are
  - Easy to specify queries using a query language: Structured Query Language (SQL)

```
SELECT S.name
FROM Students S
WHERE S.sid = 123456
```

  - Efficient query processor to get answer

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Transaction Management

- A transaction is an execution of a user program in a DBMS.
- Transaction management deals with two things:
  - Concurrent execution of transactions
  - Incomplete transactions and system crashes

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Concurrency Control

- Example: two travel agents (A, B) are trying to book one remaining airline seat (two transactions), only one transaction can succeed in booking.

  // num_seats is 1

  Transactions A and B: if num_seats > 0, book the seat & num_seat--;
  // overbook!

- How to solve this?

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Concurrency Control (Solution)

// num_seats is 1

Transactions A and B: if num_seats > 0, book the seat & num_seat--;
// overbook!

- Solution: use locking protocol

  Transaction A: get exclusive lock on num_seats

  Transaction B: wait until A releases lock on num_seats

  Transaction A: if num_seats > 0, book & num_seat--;
  // book the seat, num_seat is set to 0

  Transaction A: release exclusive lock on num_seats

  Transaction B: num_seats = 0, no booking; // does not book the seat

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Crash Recovery

- Example: a bank transaction transfers $100 from account A to account B

```
A = A - $100
   <system crashes>    // good for the bank!
B = B + $100
```

- How to solve this?

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Crash Recovery (Solution)

```
A = A - $100
   <system crashes>        // good for the bank!
B = B + $100
```

- Solution: use logging, meaning that all write operations are recorded in a log on a stable storage.

```
A = A - $100       // recorded A value (checkpoint) in a log
   <system crashes>
            // start recovery: read the log from disk
            //analyze, undo, & redo
```

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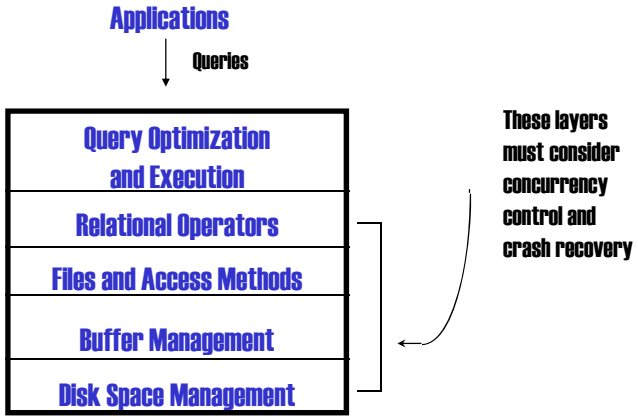
Layered Architecture



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Administration

- Hao will be away at a conference on 9/30
  - Please attend Winston's lecture at CSIE 101
- Reading assignments
  - Read Chapters 1
  - Read Chapter 2 (except 2.7) for next lecture

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