Introduction and Overview

(Read Cow book Chapter 1)

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Course Administrivia

- **Book**
  - Cow book
  - Somewhat Dense
  - Cover about 80%

- **Instructor**
  - Leonard McMillan

- **Teaching Assistant**
  - To be named

- **When will we meet?**
  - Mondays and Wednesdays (barring university holidays)
Course Logistics

- Website (not up yet): http://www.cs.unc.edu/Courses/comp521-f10
  look here first for
  - News, problem-set hints, and helpful resources
  - Revisions, solutions, and corrections to problem sets
- Office Hours: TBA
- Grading
  - 5 - Problem sets (worth 9% each)
  - 2 - Quizzes (worth 15% each)
    - Final Exam (worth 25%)
- Problem Sets
  - Roughly one every two weeks, except weeks with quizzes
Course Breakdown

- Relational Model
- Relational Algebra
- Relational Calculus
- Normal Forms

Emphasis

- Structured Query Language
- Integrating Databases & programs
- Web-based Database use
- Triggers and Active databases

Applications: 30
Systems: 35
Foundations: 35

- Database Indexing
- Query Evaluations
- Query Optimization
- Transactions and Concurrency
Where Databases fit into CS

- **Designing Programs**
  - Syntax
  - Semantics
  - Abstraction

- **Designing Algorithms**
  - Correctness
  - Efficiency

- **Designing Data**
  - Generalization
  - Portability
  - Independence

Data sets are growing far faster than either languages used to process them or the algorithms used to manage them.
What is a Database?

- A very large, integrated collection of bits.
- Models real-world *enterprise*.
  - Entities (e.g., students, courses)
  - Relationships (e.g., Madonna is taking Comp 521)
- A *Database Management System (DBMS)* is a software package designed to store and manage databases.
Files vs. Databases

- Application must stage large datasets between main memory and secondary storage (e.g., buffering, page-oriented access, 32-bit addressing, etc.)
- Special code for different queries
- Must protect data from inconsistency due to multiple concurrent users
- Crash recovery
- Security and access control
Why use a Database?

- Data Independence
- Efficient access.
- Reduced application development time.
- Data integrity and security.
- Uniform data administration.
- Concurrent access, recovery from crashes.
Why Study Databases??

- Shift from *computation* to *information*
  - at the “low end”: dynamic web spaces
  - at the “high end”: scientific applications

- Datasets increasing in diversity and volume.
  - Digital libraries, interactive video, Human Genome project, Earth-Observing Satellite (EOS) project
  - ... need for DBMS exploding

- DBMS encompasses most of CS
  - OS, languages, theory, AI, multimedia, logic
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 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 allowed contents of columns, or fields.
Levels of Abstraction

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

Schemas are defined using Data-Description Languages (DDLs); data is modified/queried using Data-Management Languages (DMLs).
Example: University Database

- Conceptual schema:
  - `Students(sid: string, name: string, login: string, dob: date, 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 actually 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 multiple user queries is essential for good DBMS performance.
  - Because disk accesses are frequent, and relatively slow, it is important to keep the CPU humming by 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.
Database Transactions

- Key concept is *transaction (Xact)*, which is an *atomic* sequence of database actions.
- 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!
Scheduling Concurrent Transactions

- DBMS ensures that execution of \{T_1, \ldots, T_n\} is equivalent to some \textit{serial} execution T_1' \ldots T_n'.
  - 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. \textit{(Strict Two-Phase Locking (2PL) protocol.)}
  - \textbf{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? \textit{(Deadlock!)} Ti or Tj is \textit{aborted} and restarted!
DBMS ensure *atomicity* (all-or-nothing property) even if system crashes in the middle of a Xact.

**Idea:** Keep a *log* (history) of all actions carried out by the DBMS while executing a set of Xacts:

- **Before** a change is made to the database, the corresponding log entry is forced to a safe location. (Write-Ahead Log (**WAL**) protocol)
- **After** a crash, the effects of partially executed transactions are *undone* using the log. (Thanks to WAL, if log entry wasn’t saved before the crash, corresponding change was not applied to database!)
The Log

The following actions are recorded in the log:

- **Ti writes an object**: The old value and the new value.
  - Log record must go to disk before the changed page!
- **Ti commits/aborts**: A log record indicating this action.

Log records chained together by Xact id, so it’s easy to undo a specific Xact (e.g., to resolve a deadlock).

Log is often duplexed and archived on “stable” storage.

All log related activities (and in fact, all CC related activities such as lock/unlock, dealing with deadlocks etc.) are handled transparently by the DBMS.
Databases make these folks happy ...

- End users (Banks, Retailers, Scientists)
- DBMS vendors (Oracle, IBM, Microsoft)
- DB application programmers
  - Makes life easier since
    Database provides guarantees
- Database administrator (DBA)
  - Designs logical/physical schemas
  - Handles security and authorization
  - Data availability, crash recovery
  - Database tuning as needs evolve

Last three must understand how a DBMS works!
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.
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 growth areas in CS.
Next Time

- Modeling Data
- The Entity-Relationship (ER) model