CSC443
Database Management Systems

Instructor: Sayyed Nezhadi

Winter 2019

Logistics

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Course Information

- Prerequisite
  - CSC343H1/434H1
  - CSC369H1/468H1
  - 364H1/CSC373H1/CSC375H1
  - Prerequisites are strictly enforced

- This course requires a lot of time commitment!!

Collaboration

- We will be using Piazza as our main discussion board. You are responsible for reading all postings made by me or the TAs.

- For personal questions, email us from your UofT address. Please include "csc443" in the subject line and include your full name.

Problem Sets and Final Project

- **3 Problem Sets**
  - No programming is required

- **Final Project**
  - Major Programming Assignment
  - Must be done as a team(3-4 people)
  - You will develop a database management system
  - You will present your project in the class (the last two weeks)
  - You will submit a project report along with all your codes
  - You need to allocate enough time for this project

Grading

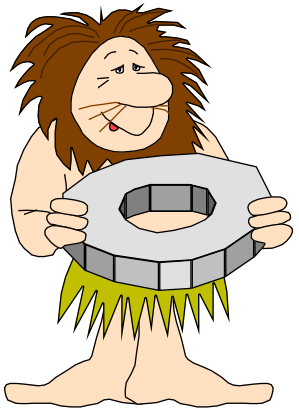
Work	Notes	Weight	Due Date
Problem Set 1		15%	Feb 10, 2019
Problem Set 2		15%	Feb 24, 2019
Problem Set 3		15%	Mar 10, 2019
Test (in class)		10%	Mar 22, 2019
Final Project		45%	Mar 24, 2019

* All dates are tentative

Late policy

- Problem sets will be submitted electronically (MarkUs)
- Due at 11:59pm on due date
- You can submit up to 2 days late
- 10% penalty for each day

What is a DBMS?



- A very large, integrated collection of data.
- Models real-world *enterprise.*
  - Entities (e.g., students, courses)
  - Relationships (e.g., George is taking CS443)
- A *Database Management System (DBMS)* is a software package designed to store and manage databases.

Files vs. DBMS

- Application must stage large datasets between main memory & secondary storage (e.g., buffering, page-oriented access, 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 DBMS?

- Data independence and efficient access
- Reduced application development time
- Data integrity and security
- Uniform data administration
- Concurrent access, recovery from crashes.

Why Study Databases?

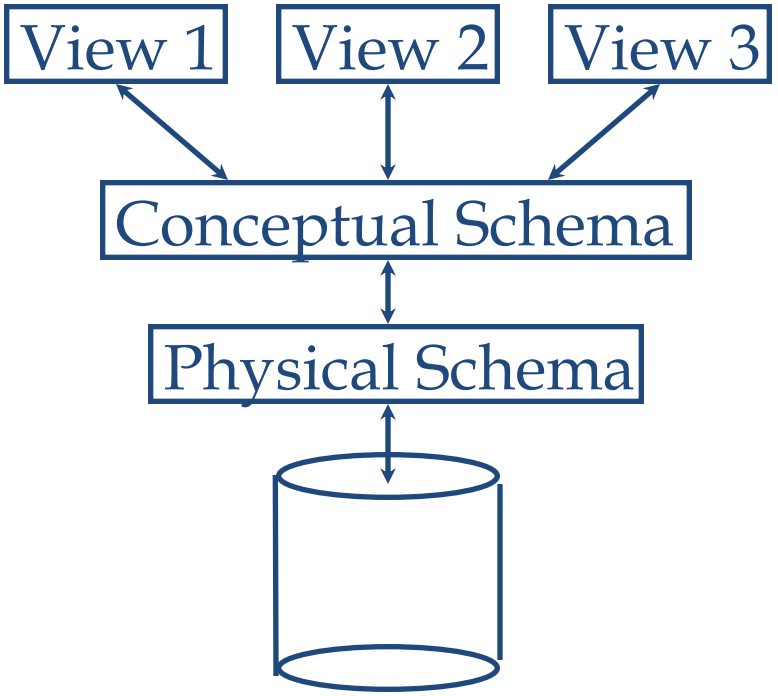
- Shift from *computation* to *information*
  - at the "low end": scramble to webspace (a mess!)
  - at the "high end": scientific applications
- Datasets increasing in diversity and volume.
  - Digital libraries, interactive video, Human Genome project, EOS project, Linked Open Data
  - ... need for 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 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 (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 DDL; data is modified/queried using DML.*

Example: University Database

- Example 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)*
- Example Physical schema:
  - Relations stored as unordered files.
  - Index on first column of Students.
- Example 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 humming by working on several user programs concurrently.
- Interleaving actions of different user programs can lead to inconsistency
  - 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 *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).

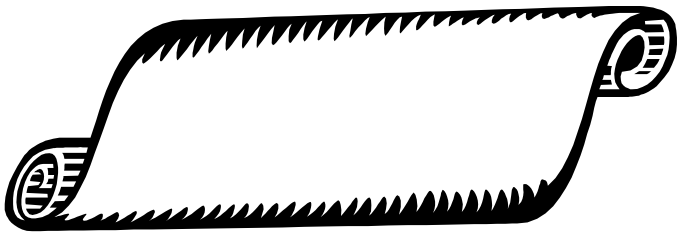
Scheduling Concurrent Transactions

- 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 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. (*WAL protocol*; OS support for this is often inadequate.)
  - Write Ahead Log (WAL), if log entry wasn't saved before the crash, corresponding change was not applied to database!
- After a crash, the effects of partially executed transactions are *undone* using the log.
  - Write Ahead Log (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 activities such as lock/unlock, dealing with deadlocks etc.) are handled transparently by the DBMS.

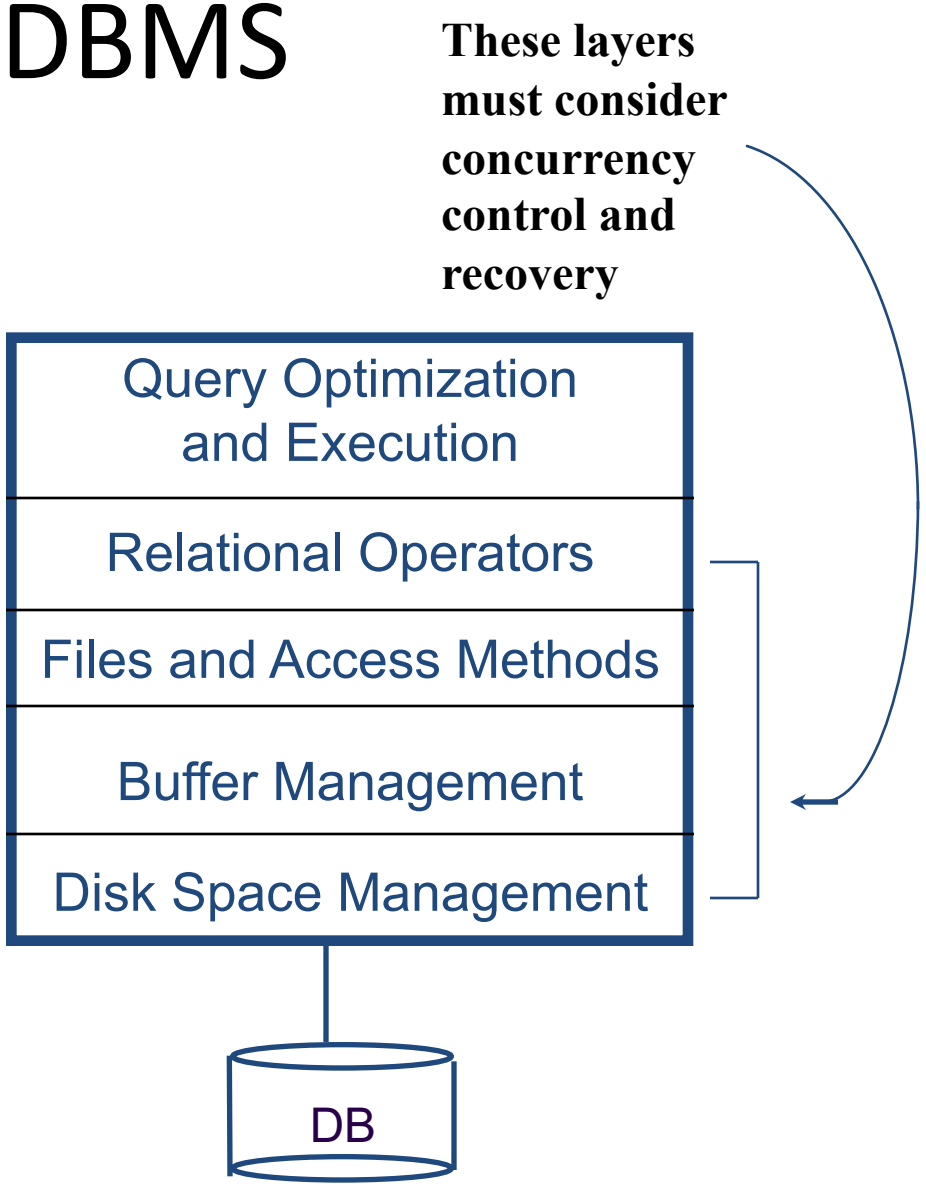
Databases make these folks happy ...

- End users and DBMS vendors
- DB application programmers
  - E.g., smart 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!

Structure of a DBMS

- 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 areas in CS.