Database Management Systems

Chapter 1

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CS44800 Versus CS34800

- Consider the difference between the following two courses:
  - How to program using Java?
  - How to implement a Java compiler?
- CS34800:
  - How to program using databases?
- CS44800:
  - How to implement the engine for a database management system?

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CS44800 Versus CS34800 (Cont'd)

- **CS34800: Information Systems**
  - From a developer's/database programmer point of view
- **CS44800: Introduction to Relational Database Management Systems**
  - Under-the-hood stuff
  - How to build your own SQL Server system, Oracle, or IBM DB2

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CS 34800: Information Systems (Developer/Programmer)

- The Relational Model and its Underlying Algebra
- SQL and Other Relational Languages
- Database Modeling and Design
- Integrity, Privacy, and Security in Relational Data Systems
- Normalization Theory
- Object-Relational, XML, and Semantic Web Databases
- Transaction Management, the ACID Properties, and Concurrency Control
- Data Analysis and Mining, and Information Retrieval
- Graph Databases

CS 44800: Introduction to Relational Database Management Systems (Under-the-Hood)

- Big project component:
  - Building your own mini-relational DBMS
- The Relational Model and SQL Relational Algebra and Calculus
- Disk and Buffer Management and Realizing a Vanilla Relation
- Disk-based Indexing Techniques (B+-trees and Hash tables)
- Query Evaluation Pipelines and Query Processing Techniques
- Query Optimization
- Concurrency Control Techniques
- Crash Recovery and Transaction Abortion Techniques
- Parallel and Distributed Query Processing Algorithms

CS44800

- Will focus on the implementation techniques for *relational* database engines
- Let us study the course web site:
  - http://www.cs.purdue.edu/homes/aref/Spring2020CS448/coursehome.html

What Is a DBMS?

- A very large, integrated collection of data.
- Models real-world *enterprise.*
  - Entities (e.g., students, courses)
  - Relationships (e.g., Madonna is taking CS564)
- A *Database Management System (DBMS)* is a software package designed to store and manage databases.

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Files vs. DBMS

- Application must stage large datasets between main memory and secondary storage (e.g., buffering, page-oriented access, 64-bit addressing, etc.)
- Special code for different queries
- Must protect data from inconsistency due to multiple concurrent users
- Crash recovery
- Security and access control

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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

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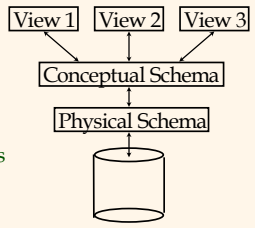
data independence: data structure will not effect application

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 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

- 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 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.

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!

in one step, either done or not

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.)
  - 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 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!

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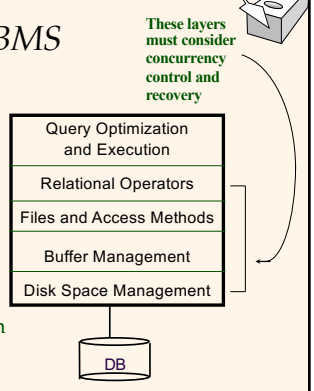
Structure of a DBMS

- 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.



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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.

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