

Database Management Systems

Chapter 1 ECS 165A – Winter 2026



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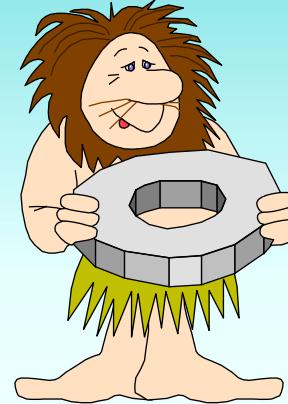
UCDAVIS
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Apache
ResilientDB
Incubating



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 ECS165)
- ❖ 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 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

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??



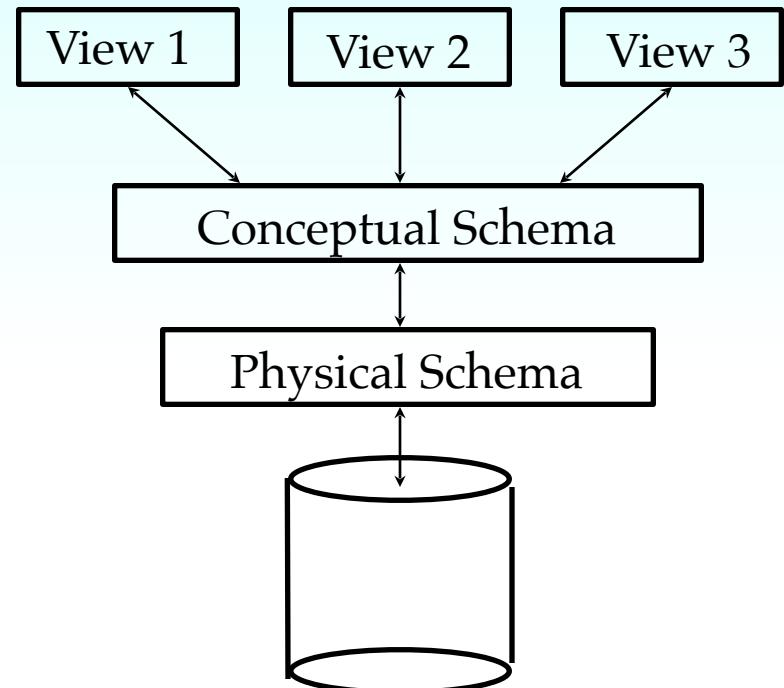
- ❖ Shift from *computation* to *information*
- ❖ Datasets increasing in diversity and volume.
 - Digital libraries, interactive video, Human Genome project, EOS project
 - ... need for DBMS exploding
- ❖ DBMS encompasses most of CS
 - OS, languages, theory, AI, multimedia, logic

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 columns, or fields.

Levels of Abstraction

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



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)*

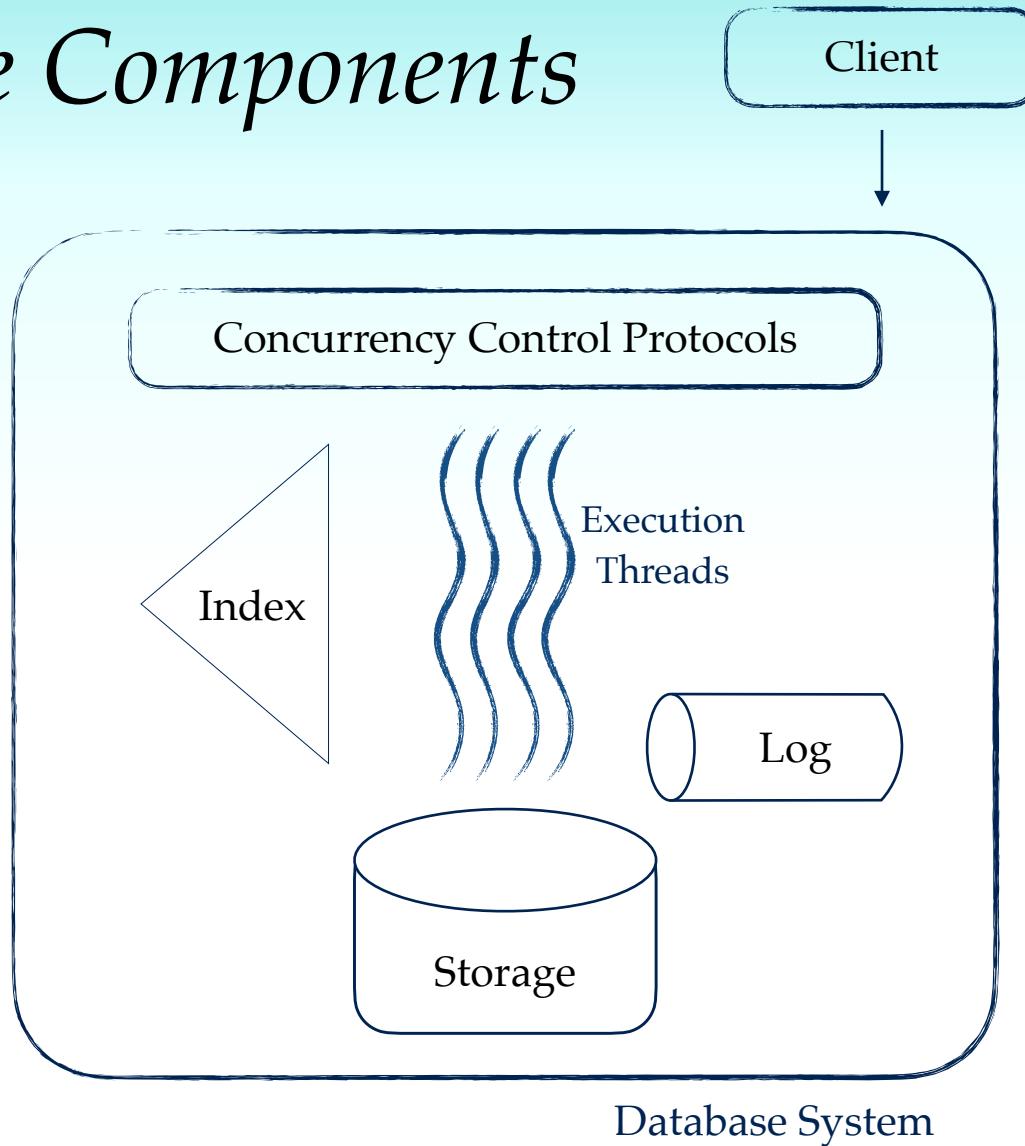
❖ Physical schema:

- Relations stored as unordered files.
- Index on first column of Students.

❖ External Schema (View):

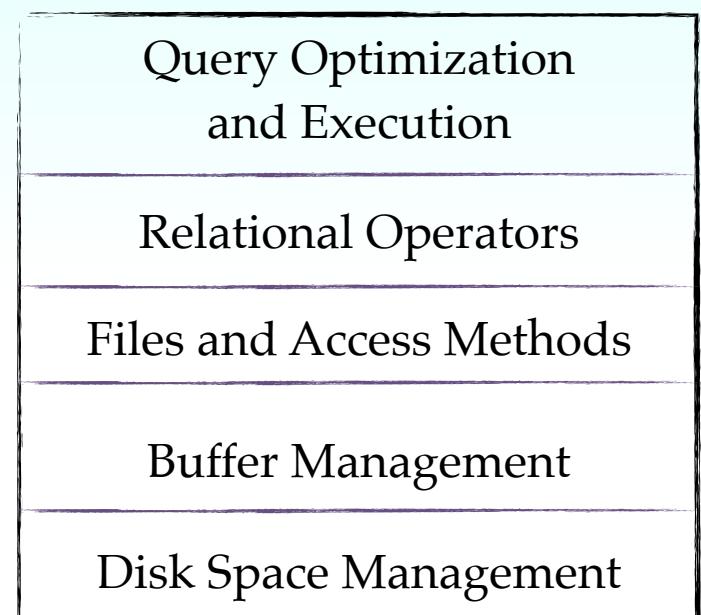
- *Course_info(cid:string,enrollment:integer)*

Database Components



Structure of a DBMS

These layers
must consider
concurrency
control and
recovery



Storage

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.

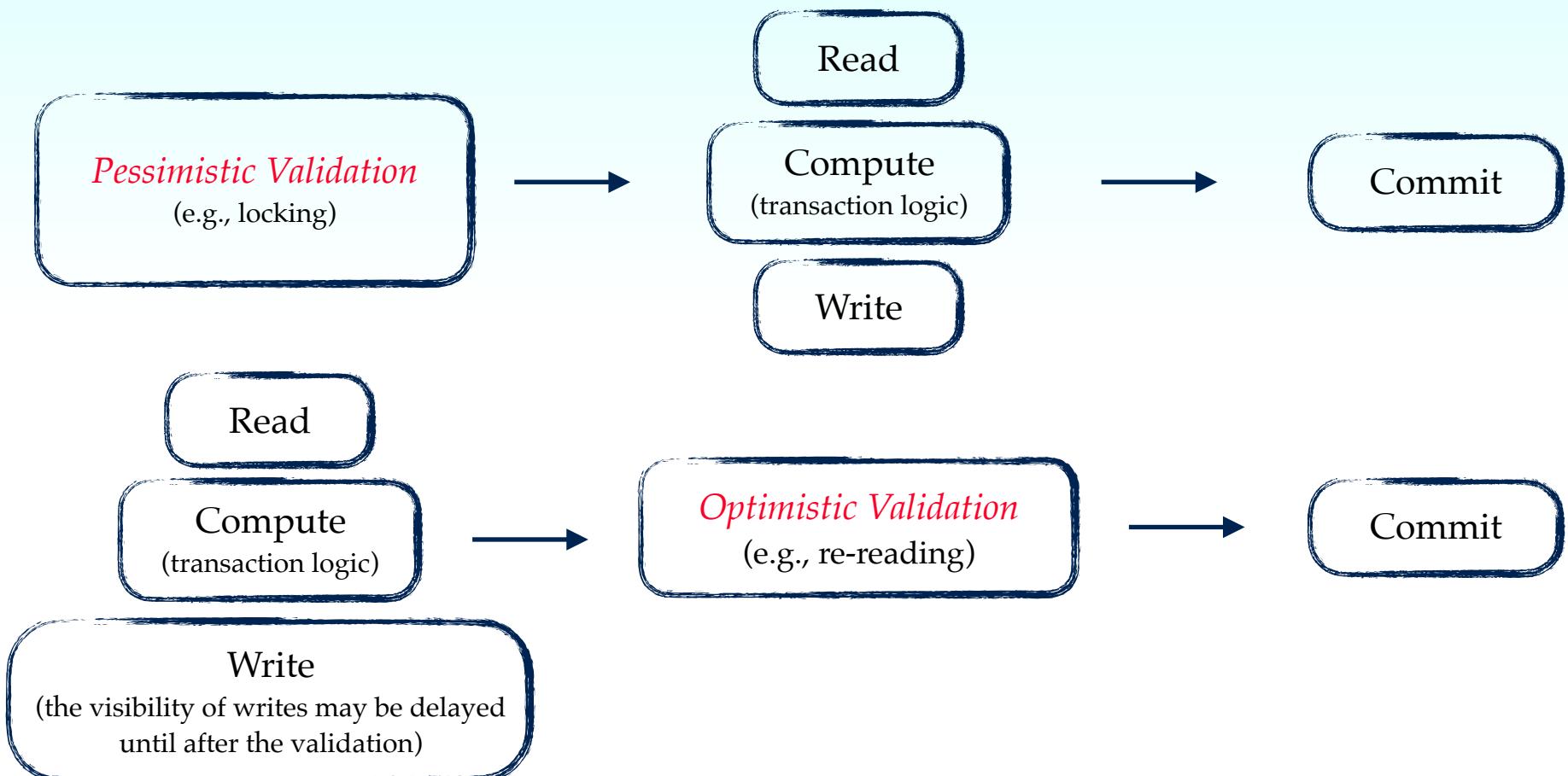
Concurrency Control

- ❖ Concurrent execution of user programs is essential for good DBMS performance.
 - Because disk (or even memory?) 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!**

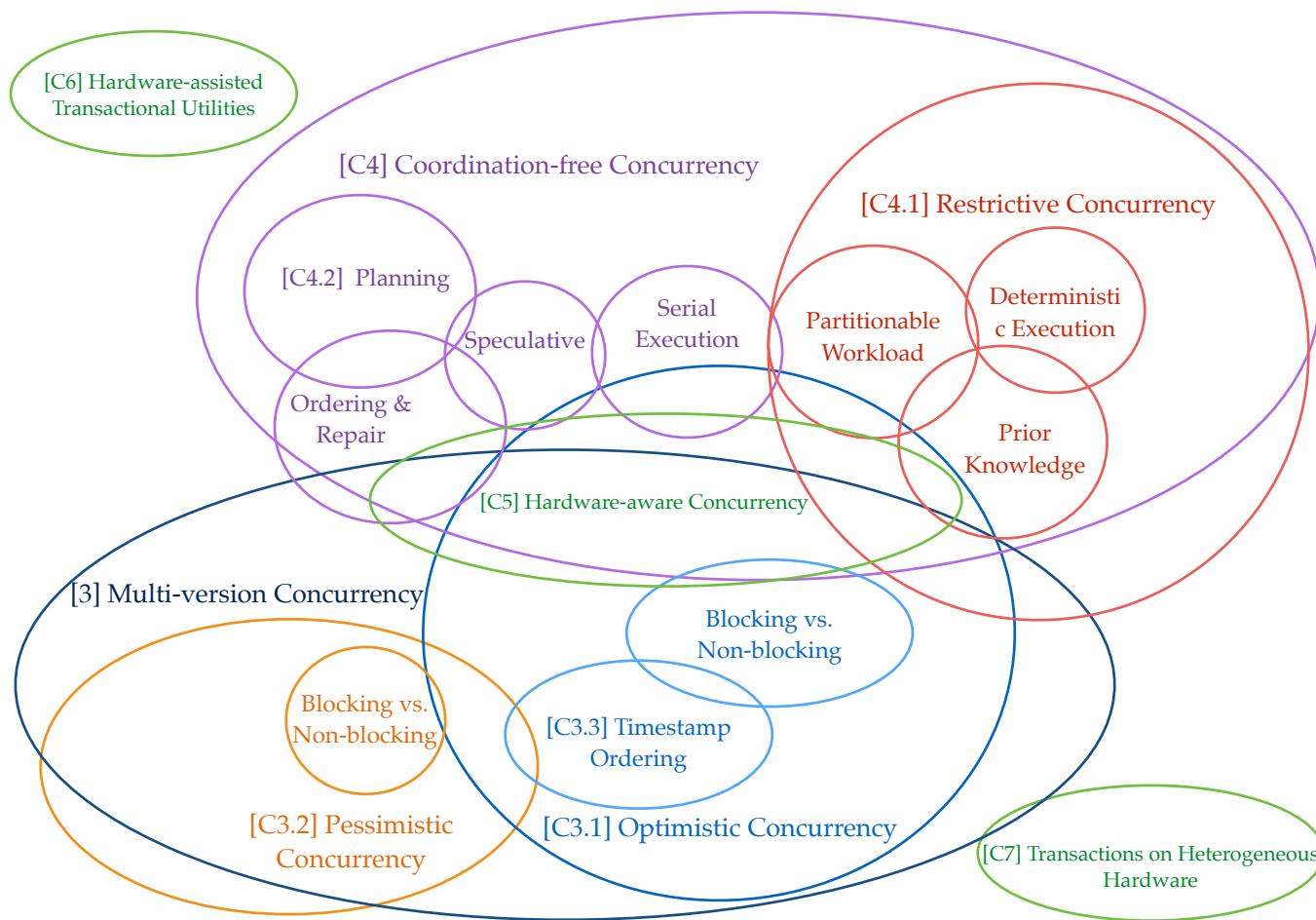
Pessimistic vs. Optimistic CC Schedule



Scheduling Concurrent Transactions

- ❖ DBMS ensures that execution of $\{T_1, \dots, T_n\}$ is equivalent to some *serial* execution $T'_1 \dots T'_n$.
 - 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. (e.g., *Strict 2PL locking protocol*, a *pessimistic protocol*.)
 - **Idea:** Suppose an action of T_i (say, writing X) affects T_j (which perhaps reads X). Let's say T_i will obtain the lock on X first and T_j is forced to wait until T_i completes; this effectively orders the transactions.
 - What if T_j already has a lock on Y and T_i later requests a lock on Y ? (*Deadlock!*) T_i or T_j is *aborted* and restarted!

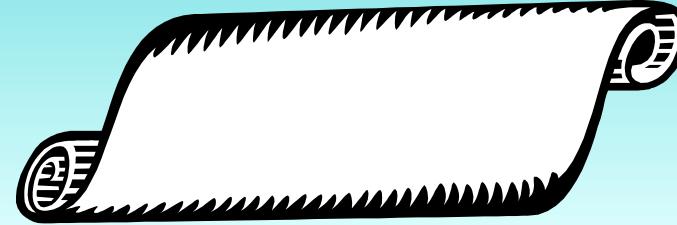
Pessimistic vs. Optimistic CC Schedule



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!)

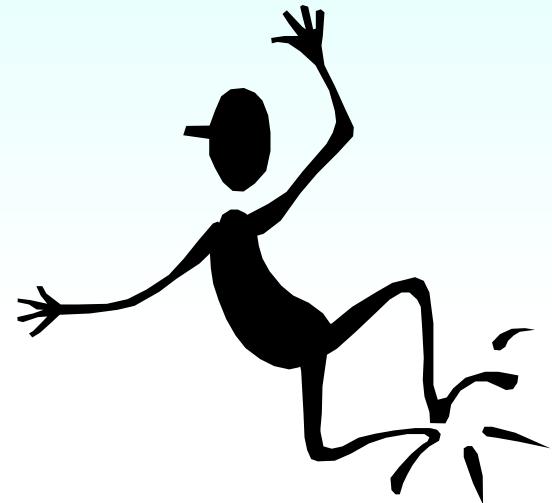
The Log



- ❖ 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., Instagram App
- ❖ 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!

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 & Data Scientists are **well-paid!** ☺
- ❖ DBMS R&D is one of the broadest, most exciting areas in CS.

