



Database Management Systems




Chapter 1

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


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, 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

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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.

Why Study Databases??



- ❖ Shift from *computation* to *information*
 - at the "low end": scramble to webspaces (a mess!)
 - at the "high end": scientific applications
- ❖ 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, "A" I, multimedia, logic

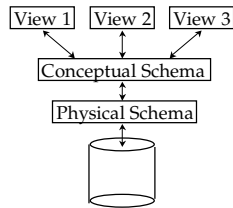
Data Models



- ❖ 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*.
 - 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!

Scheduling Concurrent Transactions



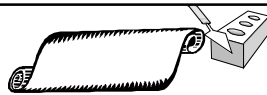
- ❖ DBMS ensures that execution of $\{T_1, \dots, T_n\}$ is equivalent to some serial execution $T_1' \dots T_n'$.
 - Before reading/writing an object, a transaction requests a lock on the object, and waits till the DBMS gives it the lock. All locks are released at the end of the transaction. (Strict 2PL locking protocol.)
 - Idea: If an action of T_i (say, writing X) affects T_j (which perhaps reads X), one of them, 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!

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 ...

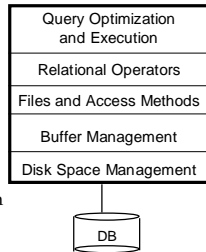


- ❖ End users and DBMS vendors
 - ❖ DB application programmers
 - E.g. smart webmasters
 - ❖ Database administrator (DBA)
 - Designs logical / physical schemas
 - Handles security and authorization
 - Data availability, crash recovery
 - Database tuning as needs evolve
- Must understand how a DBMS works!*



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.