

Introduction to database management systems

Iztok Savnik, FAMNIT

Slides

- Raghu Ramakrishnan, Johannes Gehrke, Database Management Systems, McGraw-Hill, 3rd ed., 2007.
- Slides from „Cow Book“: R.Ramakrishnan, <http://pages.cs.wisc.edu/~dbbook/>

Basic information

- *Lecturer:* Iztok Savnik
- *Asistent:* Uroš Sergaš
- *Exercises:* Auditorial + laboratory
- *Appointement:* After the lecture, mail
- *Grading:*
 - Written exam
 - Homework
 - Quizzes

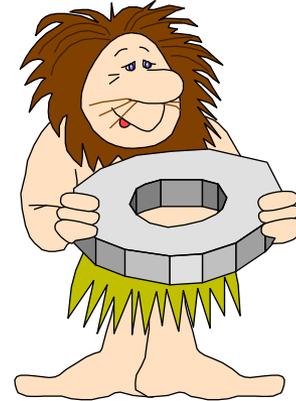
Literature

- Textbook
 - Raghu Ramakrishnan, Johannes Gehrke, Database Management Systems, McGraw-Hill, 3rd ed., 2007.
- Transparencies
 - „Cow Book“: R.Ramakrishnan, <http://pages.cs.wisc.edu/~dbbook/>
- Additional literature
 - Abraham Silberschatz, Henry F. Korth, S. Sudarshan, Database System Concepts, 3rd ed., McGraw-Hill, 1997.

Grading

- Written exam – 40%
 - 4 exercises ~ 90-120 min
 - Exercises close to those from tutorials and lectures
 - > 50% !
- Homework – 40%
 - 3 homework ~ 3 topics
 - Topics from lectures and exercises
 - > 50% !
- Oral exam – 20%
 - After written exam and homework
 - 3 questions from tutorials and lectures
 - Final grade is formed

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.

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

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??



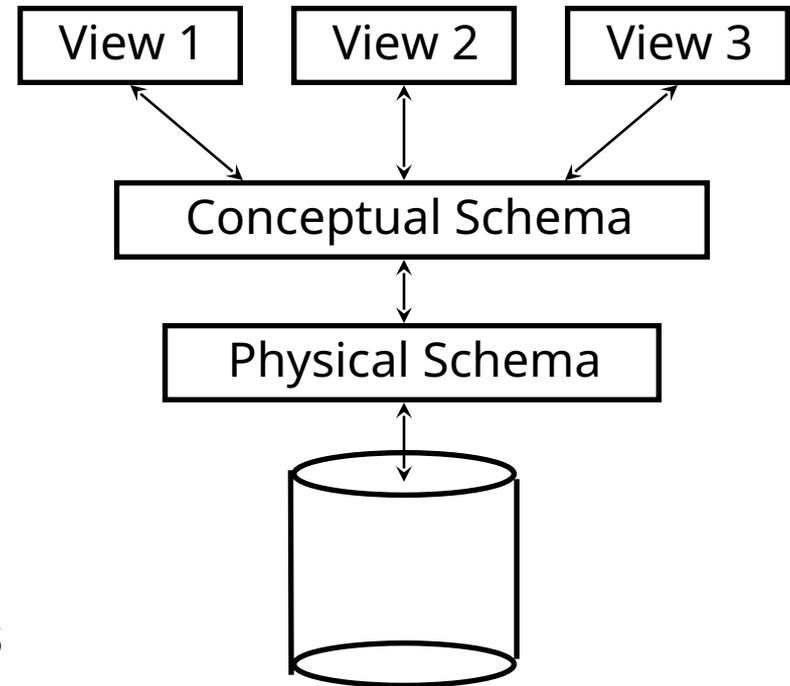
- Shift from computation to information
 - at the “low end”: scramble webspace (a mess!)
 - at the “high end”: scientific applications
- Datasets increasing in diversity and volume.
 - Digital libraries, Interactive video, Human Genome project, Knowledge graphs, Sky survey, etc.
 - ... need for DBMS 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

- 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!

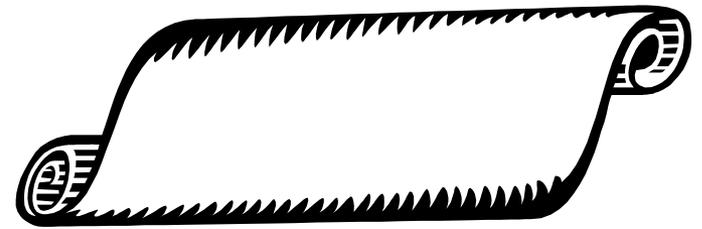
Scheduling Concurrent Transactions

- 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

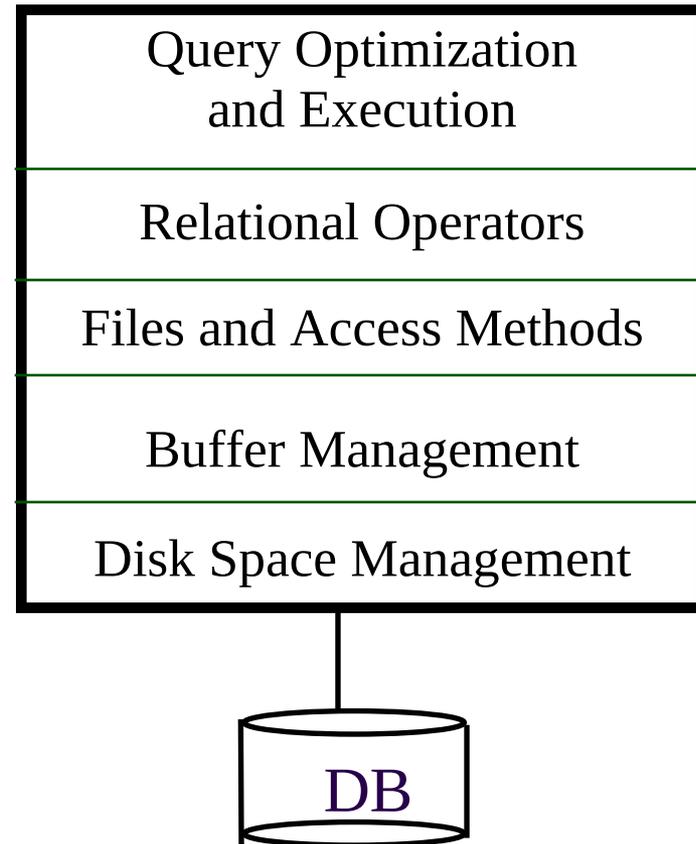


Must understand how a DBMS works!

Structure of a DBMS

These layers must consider concurrency control and recovery

- 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.



Syllabus (short)

1. Introduction
2. Relational data model
 - Relational algebra
 - Relational calculus
3. Relational query languages
 - SQL
 - QBE
4. Storage system
 - Disks
 - Memory management
 - Indexes
5. Query evaluation
 - Physical relational ops
 - Query optimization
6. Transactions
 - Concurrency control
 - Recovery
7. Relational database design
 - Logical design
 - Physical design
8. Conceptual data models
 - Data model ER
 - Extended ER model
9. New database systems
 - NoSQL systems
 - Key/value, document, columnar, and graph stores

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

