Introduction to DBMS

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Introduction

- The history of Database Management System (DBMS)
- Overview of DBMS
- The relational model

Introduction to Database Systems

- What is a Database System?
  - Database (data , metadata)
  - Hardware (disks)
  - Software (DBMS)
  - People (users, database designers and database administrators DBA)

What is a DBMS?

- Database Management System (DBMS) = a software contains a set of instructions to access/manipulate data
- Examples?
  - Search engines, banking systems, airline reservations, corporate records, payrolls, sales inventories.
  - New applications: Wikis, biological/multimedia/scientific/geographic data.

Features of a DBMS

- Support massive amounts of data
  - Giga/tera/petabytes
  - Far too big for main memory

- Persistent storage
  - Programs update, query, manipulate data.
  - Data continues to live long after program finishes.

- Efficient and convenient access
  - Efficient: do not search entire database to answer a query.
  - Convenient: allow users to query the data as easily as possible (query compiler).
- Secure data access
  - Allow multiple users to access database simultaneously.
  - Allow a user access to only to authorized data.
  - Provide some guarantee of reliability against system failures.

A Brief History of DBMS

- The earliest databases (1960s) evolved from file systems
  - File systems
    - Allow storage of large amounts of data over a long period of time
    - File systems do not support:
      - Efficient access of data items whose location in a particular file is not known
      - Logical structure of data is limited to creation of directory structures
      - Concurrent access: Multiple users modifying a single file generate non-uniform results
    - Navigational and hierarchical

- Relational DBMS (1970s to now)
  - View database in terms of relations or tables
  - High-level query and definition languages such as SQL
  - Allow user to specify what (s)he wants, not how to get what (s)he wants

- Object-oriented DBMS (1980s)
  - Inspired by object-oriented languages

More detailed History

- 1950s and early 1960s:
  - Data processing using magnetic tapes for storage
    - Tapes provided only sequential access
  - Punched cards for input
- Late 1960s and 1970s:
  - Hard disks allowed direct access to data
  - Network and hierarchical data models in widespread use
  - Ted Codd defines the relational data model
    - he won the ACM Turing Award for this work
    - IBM Research begins System R prototype
    - UC Berkeley begins Ingres prototype

More detailed History

- 1980s:
  – Research relational prototypes evolve into commercial systems
    - SQL becomes industrial standard

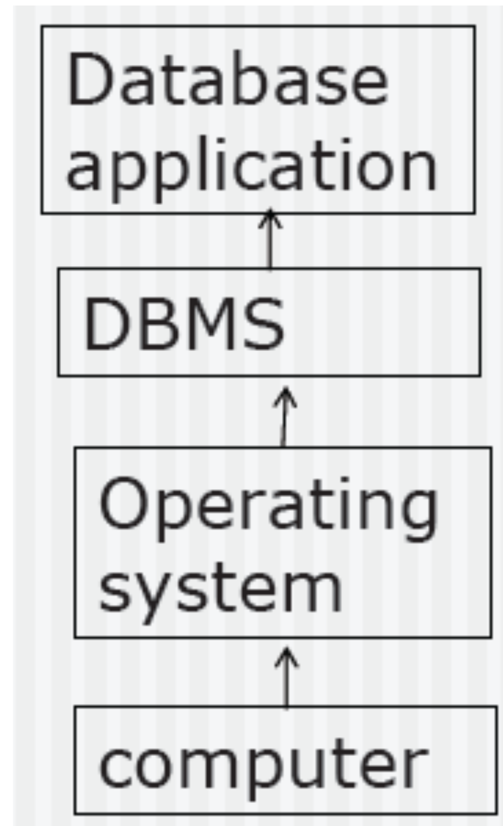
  – Parallel and distributed database systems (vs. centralized and client–server database systems)
    - A parallel database system seeks to improve performance through parallelization of various operations, such as loading data, building indexes and evaluating queries by using multiple CPUs and disks in parallel.
    - A distributed database is a database in which storage devices are not all attached to CPU. It may be stored in multiple computers located in the same physical location, or may be dispersed over a network of computers.

More detailed History

- 1990s:
  - Large decision support and data-mining applications
  - Large multi-terabyte data warehouses
  - Emergence of Web commerce
- 2000s:
  - XML and XQuery standard

Overview of database systems

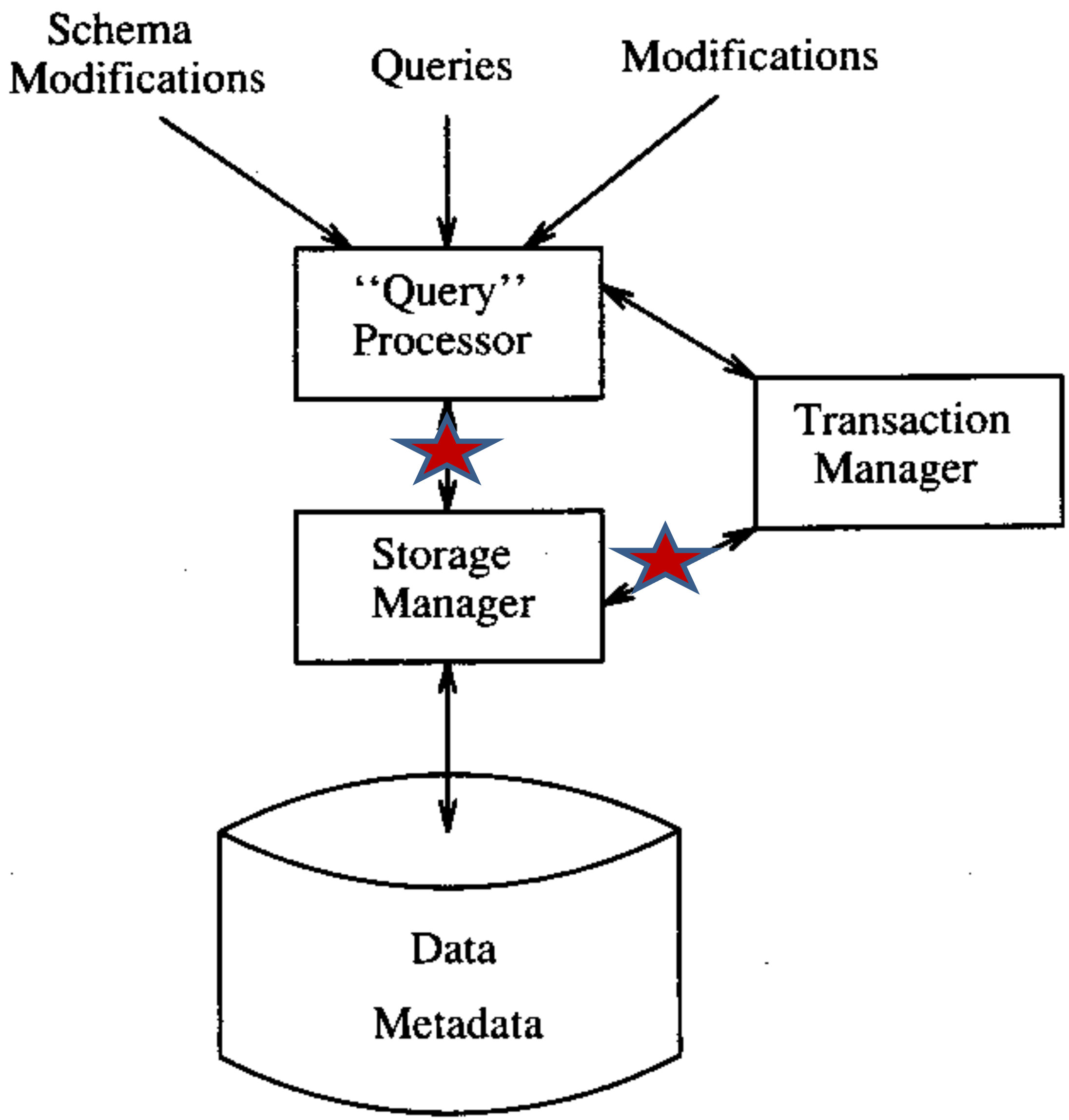
- Database applications
- Database Management System
- Operating System (not in this course)



The DBMS Industry

- A DBMS is a software system.
- Major DBMS vendors: Oracle, Microsoft, IBM, Sybase
- Free/Open-source DBMS: MySQL, PostgreSQL, Firebird.
- All are “relational” DBMS.

DBMS Architecture



DBMS (Components)

- Query processor
  - The portion of the DBMS that most affects the performance
  - The query compiler: translate query into an internal form called query plan
  - execution engine: execute each of the steps in the chosen query plan
- Transaction manager
  - Logging, concurrency control
- Storage manager
  - Control the placement of data on disk, and its movement between disk and main memory

The Relational Model

The Relational Model

- Simple: Built around a single concept for modeling data: the relation or table.
  - A relational database is a collection of relations.
  - Each relation is a table with rows and columns.

- Supports high-level programming language (SQL).
  - Limited but very useful set of operations
  - Enables programmers to express their wishes at a very high level

- Has an elegant mathematical design theory.
- Most current DBMS are relational.

Relations

- A relation is a two-dimensional table:
  - Relation ≈ table.
  - Attribute ≈ column name.
  - Tuple ≈ row (not the header row).
- Database ≈ collection of relations.
- A relation has two parts:
  - Schema defines column heads of the table (attributes).
  - Instance contains the data rows (tuples, rows, or records) of the table.

Student	Course	Grade
Hermione Grainger	Potions	A-
Draco Malfoy	Potions	B
Harry Potter	Potions	A
Ron Weasley	Potions	C

Schema

CoursesTaken :

Student	Course	Grade
Hermione Grainger	Potions	A-
Draco Malfoy	Potions	B
Harry Potter	Potions	A
Ron Weasley	Potions	C

- The schema of a relation is the name of the relation followed by a parenthesized list of attributes.

```
CoursesTaken(Student, Course, Grade)
```

- A design in a relational model consists of a set of schemas.
- Such a set of schemas is called a relational database schema.

Equivalent Representations of a Relation

CoursesTaken :

Student	Course	Grade
Hermione Grainger	Potions	A-
Draco Malfoy	Potions	B
Harry Potter	Potions	A
Ron Weasley	Potions	C

`CoursesTaken(Student, Course, Grade)`

- Relation is a **set** of tuples and not a list of tuples.
  - Order in which we present the tuples does not matter.

- The attributes in a schema are also a set (not a list).
  - Schema is the same irrespective of order of attributes.

    `CoursesTaken(Student, Grade, Course)`
  - We specify a “standard” order when we introduce a schema.
- How many equivalent representations are there for a relation with m attributes and n tuples? m! n!

Degree and Cardinality

CoursesTaken :

Student	Course	Grade
Hermione Grainger	Potions	A-
Draco Malfoy	Potions	B
Harry Potter	Potions	A
Ron Weasley	Potions	C

- Degree is the number of fields/attributes in schema (=3 in the table above)
- Cardinality is the number of tuples in relation (=4 in the table above)

Example

- Create a database for managing class enrollments in a single semester. You should keep track of all **students** (their names, Ids, and addresses) and **professors** (name, Id, department). Do not record the address of professors but keep track of their ages. Maintain records of **courses** also. Like what classroom is assigned to a course, what is the current enrollment, and which department offers it. At most one professor **teaches** each course. Each student **evaluates** the professor teaching the course. Note that all course offerings in the semester are unique, i.e. course names and numbers do not overlap. A course can have ≥ 0 **pre-requisites**, excluding itself. A student enrolled in a course must have enrolled in all its pre-requisites. Each student receives a **grade** in each course. The **departments** are also unique, and can have at most one chairperson (or dept. head). A chairperson is not allowed to head two or more departments.

Relational Design for the Example

- Students (PID: *string*, Name: *string*, Address: *string*)
- Professors (PID: *string*, Name: *string*, Office: *string*, Age: *integer*, DepartmentName: *string*)
- Courses (Number: integer, DeptName: *string*, CourseName: *string*, Classroom: *string*, Enrollment: *integer*)
- Teach (ProfessorPID: *string*, Number: *integer*, DeptName: *string*)
- Take (StudentPID: *string*, Number: *integer*, DeptName: *string*, Grade: *string*, ProfessorEvaluation: integer)
- Departments (Name: *string*, ChairmanPID: *string*)
- PreReq (Number: *integer*, DeptName: *string*, PreReqNumber: *integer,* PreReqDeptName: *string*)

Issues to Consider in the Design

- Can we merge Courses and Teach if each professor teaches at most one course?
- Do we need a separate relation to store evaluations?
- How can we handle pre-requisites that are "or"s, e.g., you can take CS 4604 if you have taken either CS 2604 or CS 2606?
- How do we generalize this schema to handle data over more than one semester?
- What modifications does the schema need if more than one professor can teach a course?

SQL and Relational Algebra

What is SQL

- SQL = Structured Query Language (pronounced “sequel”).
- a special-purpose programming language designed for managing data in relational database management systems (RDBMS).
- SQL is declarative:
  - Say what you want to accomplish, without specifying how.
  - One of the main reasons for the commercial success of RDMBSs.
- SQL has many standards and implementations:
  - ANSI SQL
    - SQL became a standard of the American National Standards Institute (ANSI) in 1986, and of the International Organization for Standards (ISO) in 1987.
  - SQL-92/SQL2 (null operations, outerjoins)
  - SQL-99/SQL3 (recursion, triggers, objects)
  - Vendor-specific variations.

Relational Algebra

- Relational algebra is a notation for specifying queries about the contents of relations.

- Notation of relational algebra eases the task of reasoning about queries.

- Operations in relational algebra have counterparts in SQL.
- Relational Algebra: core of SQL.

What is an Algebra?

- An algebra is a set of operators and operands.
  - Arithmetic: operands are variables and constants, operators are $+, -, \times, \div$, etc.
  - Set algebra: operands are sets and operators are ∩, U,-
- An algebra allows us to construct expressions by combining operands and expression using operators and has rules for reasoning about expressions.
  - $a^2 + 2 \times a \times b + 2b$, $(a + b)^2$.
  - $R - S$, $R \cap S$.

Basics of Relational Algebra

- Operands are relations, thought of as sets of tuples.
- Think of operands as variables, whose tuples are unknown.
- Results of operations are also sets of tuples.
- Think of expressions in relational algebra as queries, which construct new relations from given relations.

- Four types of operators:
  - Select/Show parts of a single relation: projection and selection.
  - Usual set operations (union, intersection, difference).
  - Combine the tuples of two relations, such as cartesian product and joins.
  - Renaming.

Projection

- The projection operator produces from a relation R a new relation containing only some of R's columns.

- "Delete" (i.e. not show) attributes not in projection list.
- Duplicates eliminated

- To obtain a relation containing only the columns $A_1, A_2, \ldots A_n$ of R

RA: $\pi_{A_1, A_2, \ldots A_n}(R)$

SQL: **SELECT** $A_1, A_2, \ldots A_n$ **FROM** R;

Projection Example

S2

sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

$$\pi_{sname,rating}(S2)$$

sname	rating
yuppy	9
lubber	8
guppy	5
rusty	10

$$\pi_{age}(S2)$$

age
35.0
55.5

Selection

- The selection operator applied to a relation R produces a new relation with a subset of R's tuples.
- The tuples in the resulting relation satisfy some condition C that involves the attributes of R.
  - with duplicate removal

RA: $\boldsymbol{\sigma}_C (R)$

SQL: **SELECT** * **FROM** R **WHERE** C;

- The WHERE clause of a SQL command corresponds to **σ**( ).

Selection: Syntax of Conditional

- Syntax of conditional (C): similar to conditionals in programming languages.

- Values compared are constants and attributes of the relations mentioned in the FROM clause.

- We may apply usual arithmetic operators to numeric values before comparing them.

RA Compare values using standard arithmetic operators.
SQL Compare values using =, <>, <, >, <=, >=.

Selection Example

S2

<u>sid</u>	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

$$\sigma_{rating>8}(S2)$$

sid	sname	rating	age
28	yuppy	9	35.0
58	rusty	10	35.0

$$\pi_{sname,rating}(\sigma_{rating>8}(S2))$$

sname	rating
yuppy	9
rusty	10

Combining Operators