Database Systems

Lecture 1: Introduction

General Information

- Professor: Leonid Libkin
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- Lectures: Tuesday, 11:10am – 1 pm, AT LT4
- Website:
- http://homepages.inf.ed.ac.uk/libkin/teach/dbs09/index.html

Course Information

- Email:
  - Use your UoE account
  - Use ‘DBS’ in the subject line
  - Always sign using your name
  - No attachments
  - Never send me code via email
  - I will try to answer by the end of the next business day
- Academic offences: Don't!

Course information cont'd

- 3 assignments + exam
- 1st assignment (5%) - pencil/paper, relational algebra/calculus, SQL
- 2nd assignment (15%) - use postgreSQL (available on dice machines). Extensive SQL programming exercise
- 3rd assignments (5%) - pencil/paper again, database design, query processing, basics of XML
- Exam - 75%

Textbook

- Recommended:
  - *Database Managament Systems*, by R. Ramakrishnan, and J. Gehrke, McGraw Hill, 2003 (3rd Edition)

The goal:

You will learn:

- General principles of database systems that apply to all (certainly most) products you are likely to deal with.
- However, you **will not learn** system-specific issues

What will you learn in this course

- Database Design Methodology
  - start from a general application description (in verbal form)
  - abstract and optimize the requirements (ER modeling)
  - map the requirements into entities that an RDBMS understands (extract database relations)
  - optimize the relations (normalization)

What will you learn in this course (cont'd)

- Use of an RDBMS
  - write queries in a language that a DBMS understands (SQL)
  - implement your application using a language you are familiar with, suitably enhanced with SQL statements with the help of the DBMS
- Basics of XML
  - Schemas (DTDs), query languages (XPath, XQuery)

What you will not learn in this course

- System-specific issues
  - what is it that I can do in PostgreSQL but not in DB2 or Oracle, and vice versa
  - what level of query nesting is permitted in the latest version of Sybase
  - the exact syntax of Oracle's connect by prior clause
  - comparison with the with recursive clause in the SQL3 standard
  - etc etc

Why learn about databases?

- It used to be about boring things: employee records, bank records, etc.
- Today, the field covers all aspects of working with data:
  - Web search
  - Data mining
  - Scientific and medical databases
  - Integrating information
- Databases are behind almost everything you do on the Web
  - Google searches
  - Queries at Amazon, eBay, etc.
  - Trip planning (expedia etc)

What is Data Management?

- Find data (search and query)
- Update or modify data
- Ensure data consistency
- Protect data
  - from unauthorized access (access control)
  - from failures (recovery)
  - from other programs or users (concurrency control)

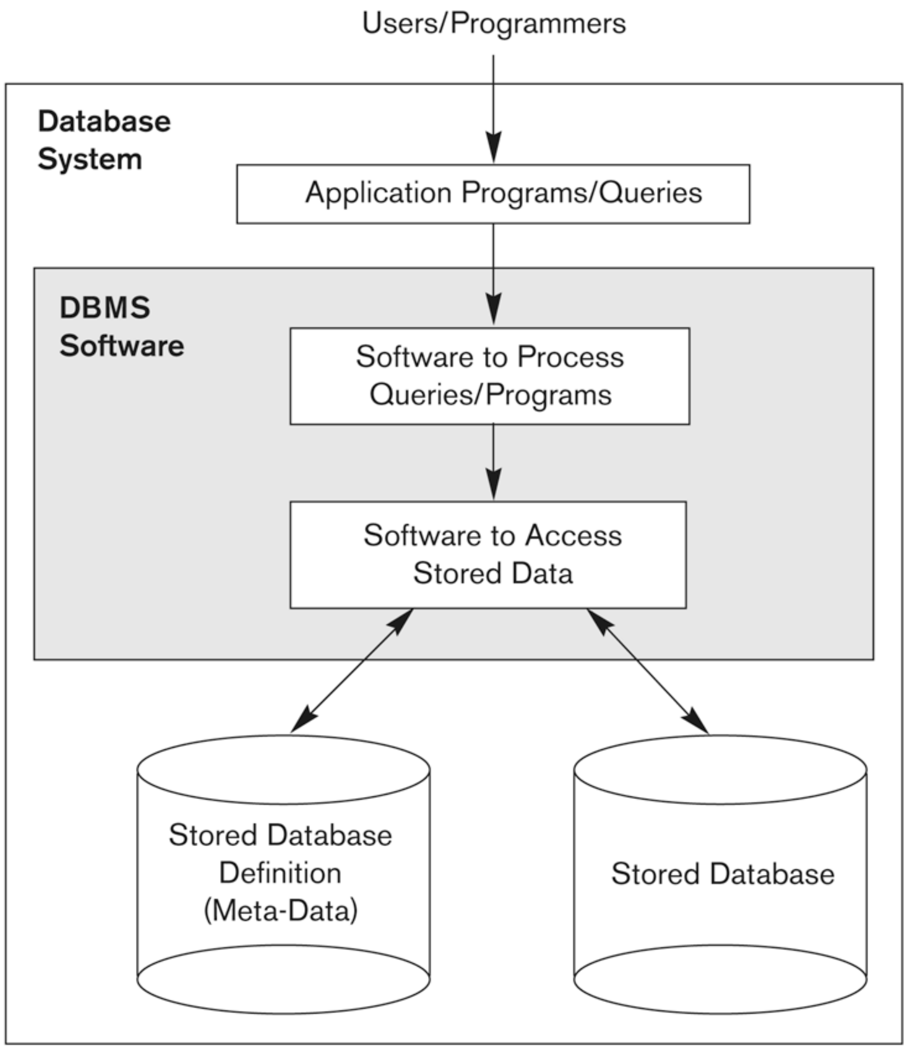
Finding data?

- Query: *Find the average enrollment in database courses at UoE?*
- How could we find this using a conventional search within file system?
  - Do we get what we want?
  - Why is this hard?
- How could we find this using a Database Management System (DBMS)?

What is a DBMS?

- **Database**: A large collection of data.
  - Examples: databases of customers, products,...
- A database usually models (some part of) a real-world **enterprise.**
  - Entities (e.g., students, courses)
  - Relationships (e.g., John Doe is taking DBS)
- A **Database Management System (DBMS)** is a software package designed to store and manage databases.
- Many vendors: IBM, Sybase, Oracle, Microsoft, etc

Simplified database system environment



A simplified database system environment.

Typical DBMS Functionality

- *Define* a particular database in terms of its data types, structures, and constraints
- *Construct* or Load the initial database contents on a secondary storage device
- *Manipulating* the database:
  - Retrieval: Querying, generating reports
  - Modification: Insertions, deletions and updates to its content
  - Accessing the database through Web applications
- *Processing* and *Sharing* by a set of concurrent users and application programs – yet, keeping all data valid and consistent

Typical DBMS Functionality

- Other features:
  - Protection or Security measures to prevent unauthorized access
  - Presentation and Visualization of data
  - Maintaining the database and associated programs over the lifetime of the database application

Why Use a DBMS?

- Self-describing nature of a database system:
  - A DBMS **catalog** stores the description of a particular database (e.g. data structures, types, and constraints)
  - The description is called **meta-data**.
- Data independence
  - You don’t need to know the implementation of the database to access the data

Why use a DBMS - Data Independence

- Applications insulated from how data is structured and stored
  - change the order of tuples
  - add or modify other columns
  - add or modify indexes
- Note that query does not change when physical structure changes

One of the most important benefits of using a DBMS

Why Use a DBMS?

- Efficient access
  - queries are optimized.
- Reduced application development time
  - Queries can be expressed declaratively, we do not need to indicate how to execute them
- Data integrity and security
  - Some constraints on the data are enforced automatically.

Why use a DBMS - Data Consistency

- Data Constraints:
  - All students must have a student ID (sID)
  - No two students can have the same sID (uniqueness)
  - A student may only have one grade per course
  - Etc.

Why Use a DBMS?

- Concurrent access, recovery from crashes
  - Many users can access/update the database at the same time without any interference.
- Speed – even when the data is huge, i.e.
  - IRS: 150 TB (1 TB ≈ 10^{12} B)
  - Yahoo: 2 PB (1 PB ≈ 10^{15} B)
  - National Energy Research Scientific Computing Center (USA): 3.5 PB

Why use a DBMS - Concurrency Control

- Concurrent execution of user programs is essential for good DBMS performance.
  - Because disk accesses are frequent, and relatively slow
- Interleaving actions of different user programs can lead to inconsistency:
  - A cheque is cleared while account balance is being computed.
- DBMS ensures that such problems do not arise: users can behave as if they were using a single-user system.

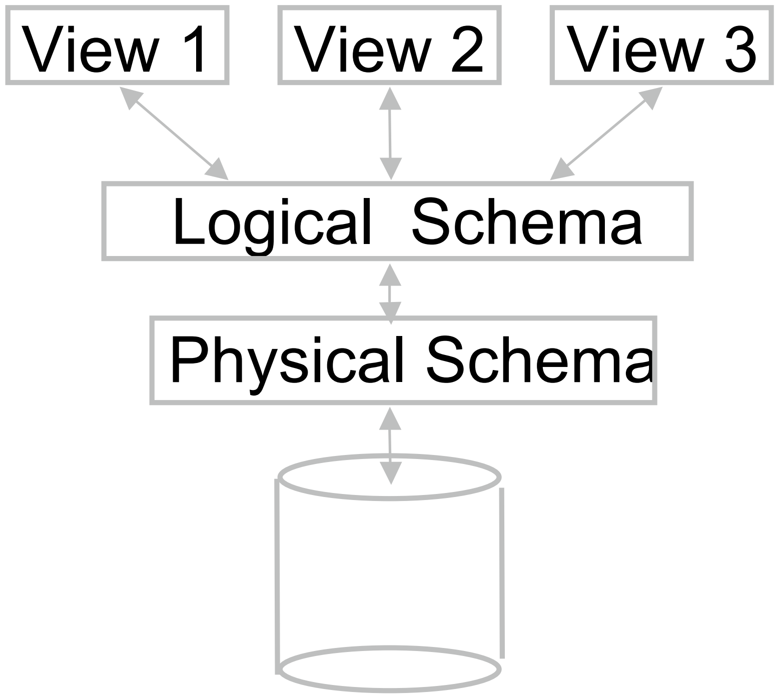
Why use a DBMS - Data Abstraction

Many **views**,

single **logical schema**

and **physical schema.**

- Views (external schemas) describe how users see the data.
- Logical schema defines logical structure.
- Physical schema describes the files and indexes used.



Example: University Database

- Conceptual schema:
  - *Student(sid: string, name: string, login: string, age: integer, gpa:real)*
  - *Course(cid: string, cname:string, credits:integer)*
  - *Enrolled(sid:string, cid:string, grade:string)*
    - *describes data in terms of the data model of the DBMS*
- Physical schema:
  - Relations stored as unordered files.
  - Index on first column of Students.
- External Schema (View):
  - *Course_info(cid:string,enrollment:integer)*

Describing Data: What is a Data Model?

- Mathematical representation of data
  - relational model = tables;
  - semistructured model = trees/graphs.

AND

- Operations on data
- Constraints

Describing Data: Data Models

- 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.

Example Instance of Student Relation

sID	Name	Login	Age	GPA
53666	Jones	Jones@cs	20	3.2
45453	Smith	Smith@ai	19	3.1

- Columns are *attributes*
- Rows are *tuples*

The SQL Query Language

- Find all students who are 20 years old

```
SELECT *
FROM Students
WHERE age = 20
```

sID	Name	Login	Age	GPA
53666	Jones	Jones@cs	20	3.2

Database Users

- Three groups:
  - End users
  - Database administrators
  - Database developers

  - This course prepares you to be end-users of DBMSs. But to be an intelligent end-user you need to know how a DBMS operates.

Historical Development of Database Technology

- Early Database Applications:
  - The Hierarchical and Network Models were introduced in the mid 1960s and dominated during the 1970s.
- Relational Model based Systems:
  - Relational model was originally introduced in 1969 (40th anniversary is celebrated this year!) by E.F. Codd at IBM.
  - Relational DBMS Products emerged in the early 1980s.

Historical Development of Database Technology (cont'd)

- Object-oriented and emerging applications:
  - Object-Oriented Database Management Systems (OODBMSs) were introduced in the late 1980s and early 1990s to cater to the need of complex data processing - but failed to take off.
  - Many relational DBMSs have incorporated object database concepts, leading to a new category called *object-relational* DBMSs (ORDBMSs)
  - *Extended relational* systems add further capabilities (e.g. for multimedia data, XML, and other data types)

Historical Development of Database Technology (cont'd)

- Data on the Web and E-commerce Applications:
  - Web contains data in HTML with links among pages.
  - This has given rise to a new set of applications and E-commerce is using new standards like XML (eXtended Markup Language).
  - Script programming languages such as PHP and JavaScript allow generation of dynamic Web pages that are partially generated from a database
    - Also allow database updates through Web pages

Extending Database Capabilities

- New functionality is being added to DBMSs in the following areas:
  - Scientific Applications
  - XML (eXtensible Markup Language)
  - Image Storage and Management
  - Audio and Video Data Management
  - Data Warehousing and Data Mining
  - Spatial Data Management
  - Time Series and Historical Data Management
  - Interoperability, integrating data from different sources