COMP9311
DATABASE SYSTEMS

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2024 Term 3; Week 1.1

Outline

- **Course Introduction**
- Database Introduction
- Database Features

Course Schedules

Lectures:

- Hybrid Mode: In-person & Online (Moodle-> Blackboard Collaborate).
  - Tutors are available to answer online questions. Post your questions online in the chatbox.
- Starts Week 1.
- Recorded (Moodle -> Lecture Recordings).

Labs:

- In-person, bring your own laptop, check your timetable (Week 2-5, 7-10)
- Guides you through the practical skills on the database application programming part of the course
- Not recorded.

Course Help

Course Website:

- https://webcms3.cse.unsw.edu.au/COMP9311/24T3/

Course Forum (Use Ed forums):

- https://webcms3.cse.unsw.edu.au/COMP9311/24T3/resources/104042
- Tutors will visit the forum regularly to answer questions

Consultation:

- Tutor present to answer any course related questions.

Course Information

How to access **Online Consultations**?

- Log into Moodle (https://moodle.telt.unsw.edu.au/).
- Go to course (COMP9311 – Database Systems).
- Click “Blackboard Collaborate”
- Click the corresponding consultation session to join.

Practices questions:

- Sample answers are provided.
- To be released on the course website at every interval.

For Other Enrolment Issues

- The course enrolment process isn't something lecturers have direct control over.
- Matters such as the number of students that can take a course/ lab etc.
- Students always adjust their courses during prior to the census date.
- Checking daily for openings is still recommended.

Course Staff

Lecturer-in-Charge

- Dr. Zhengyi Yang
- Email: zhengyi.yang@unsw.edu.au
  (for course queries, use the forums)

Tutor Team

- Mostly research students from the *Data and Knowledge Research Group*

  Course Admin – Dr. Junhua Zhang (junhua.zhang@unsw.edu.au)

  - TAs - PhD and Master by Research Students

- We have ~870 students in 24T3

Course Overview

This is an *introductory* level course of database systems.

- We will be (mostly) learning:
  - **Theory** behind relational database systems
  - **Practice** of using relational database management systems
- We will NOT be learning:
  - Design and implementation detail of databases (COMP9315)

Course Syllabus

Data modelling and database design (Week 1 and Week 2)

i. ER model, ER-to-relational

ii. Relational model (relational algebra), mapping of ER to relational model

Essentials of Database application development (Week 3 and Week 4)

i. SQL, views, stored procedures, triggers, aggregates

ii. PostgreSQL: PLpgSQL (procedural)

Formal database design theory and system architecture (Week 5 to Week 9)

i. Normalisation, functional dependencies

ii. Storage and indexing, data access operations

iii. Query processing: translation, optimisation, evaluation

iv. Transaction processing: transactions, concurrency control, recovery

v. NoSQL: NoSQL Databases for other purposes, i.e., MongoDB, Neo4j

Tentative Weekly Outline

Week	Tuesday	Wednesday
Week 1	Subject Intro, Intro to DB	Conceptual DB Design (ER)
Week 2	Relational Data Model	Relational Algebra
Week 3	SQL	SQL
Week 4	PLpgSQL	PLpgSQL
Week 5	Functional Dependencies	Normal Forms
Week 6	*Quiet Week (No Lecture)*	*Quiet Week (No Lecture)*
Week 7	Relational Database Design	Disk, File, Index
Week 8	Transaction Management	Transaction Management
Week 9	NoSQL	NoSQL/Guest Lecture
Week 10	Advanced Topics/Guest Lecture	Revision

Course Textbook

- ★ **Lecture notes will be sufficient**

Reference Books:

- ➢ **Elmasri & Navathe, *Fundamentals of Database Systems*, Benjamin/Cummings, 7th Edition, 2015.**
- ➢ J. D. Ullman & J. Widom, *A First Course in Database Systems*, Prentice Hall, 1997.
- ➢ R. Ramakrishan, *Database Management Systems*, McGRAW-HILL, 1997.
- ➢ D. Maier, *The Theory of Relational Databases*, Computer Science Press, 1983.

Course Assessments (Cont.)

COMP9311 24T2 Assessment Summary:

Number	Name	Full Mark
1	Assignment 1: Data Modelling + Relational Algebra (week 1-3)	24
2	Assignment 2: DB design Theory + Transaction (week 7-9)	26
3	Project 1: SQL, PLpgSQL (week 4-6)	50
4	Final Exam (Exam Week)	100

The equation for your final mark calculated by **Geometric Mean**:

- Final Mark = sqrt ((ass1 + ass2 + proj1) * Final Exam)

Submission

Assignments, OK to have either:

- ➢ Directly using word and then convert to PDF
- ➢ Hand-written and then convert to PDF/word

Submissions should be made through **Moodle**.

Late Submission

5% reduction per day (of the full mark) for assignments and project

- 0 marks after 5 days late
- **1 second late = 1 day late**
- Submit wrong files = Late
- Please **double check** to make sure your submission is correct and on time!

Special Consideration

- We will grant no-penalty extensions due to extreme circumstances (e.g., medical emergencies)
- Apply via *myUNSW* as soon as possible (**within 3 working days**)
- Evidence is needed, application process and details in **here**
- **No other excuses are accepted** (e.g., network down, too busy, forgot to submit)

Plagiarism

★ We adopt a **zero-tolerance** policy for plagiarism.

All submissions are checked for plagiarism. The university regards plagiarism as a form of academic misconduct and has very strict rules regarding plagiarism.

For UNSW policies, penalties, and information to help avoid plagiarism, please see: https://student.unsw.edu.au/plagiarism. *Not knowing the rules is not considered a valid excuse.*

All assessments must be your own original work. They are NOT group project.

DO NOT: copy from others, copy from the Internet, pay someone to do it.

Be careful using ChatGPT or other AI tools! There are not reliable.

https://www.student.unsw.edu.au/notices/2023/02/academic-integrity-reminder-chatgpt

The impact of AI on Computer Science Education:

https://cacm.acm.org/news/the-impact-of-ai-on-computer-science-education/

Final Exam

DO NOT go to the exam if you are not well enough to do so.

UNSW will consider your attendance **proof that you were OK** at the time of the exam. Go to the Doctor and apply for special consideration.

Learning Summary/Approach

You'll mostly be fine in our exam if you…

- Follow lectures.
- Attempt all the practice exercise questions with solutions.
- Understand the theoretical component.
- Make the most of the practical component in the lab.

Research Opportunities

- We are ranked **Top 3** worldwide for database research (CSRanking).
- Webpage: https://unswdb.github.io/

Research Degrees:

- https://research.unsw.edu.au/higher-degree-research-programs
- PhD (about 3.5 - 4 years) or MPhil (1.5 – 2 years).

Requirements:

- You received a degree previously in Computer Science or relevant fields from a world top 200 university (either overall ranking or by subject)
- WAM > 85 (UNSW standard) or equivalent

Reach out to me

- Email: zhengyi.yang@unsw.edu.au

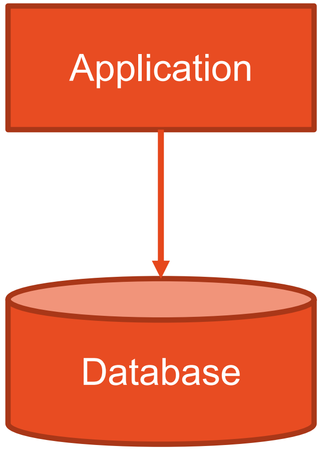
Outline

- Course introduction
- **Database introduction**
- Database features

Why Study Databases?

In real-world applications, data will always have to be:

- stored (typically on a disk device)
- manipulated/accessed (efficiently, effectively)
- shared (by many users, concurrently)
- transmitted (all around the Internet)

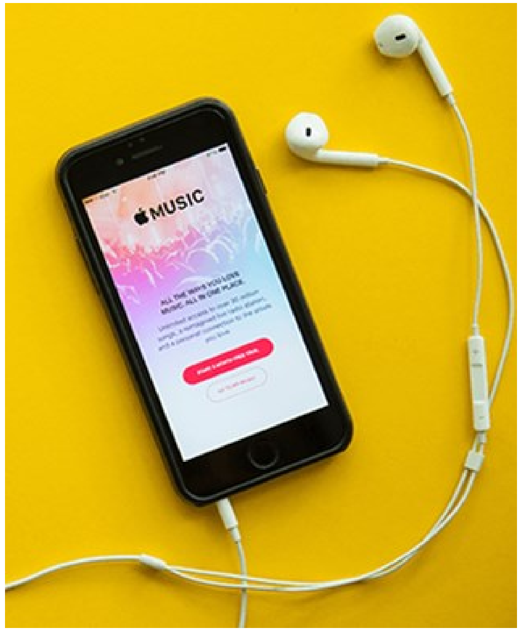


Red points are handled by databases; blue by networks.

Database: Collection of related data that models some aspect of the real world.

Databases are the core component of most computer applications.

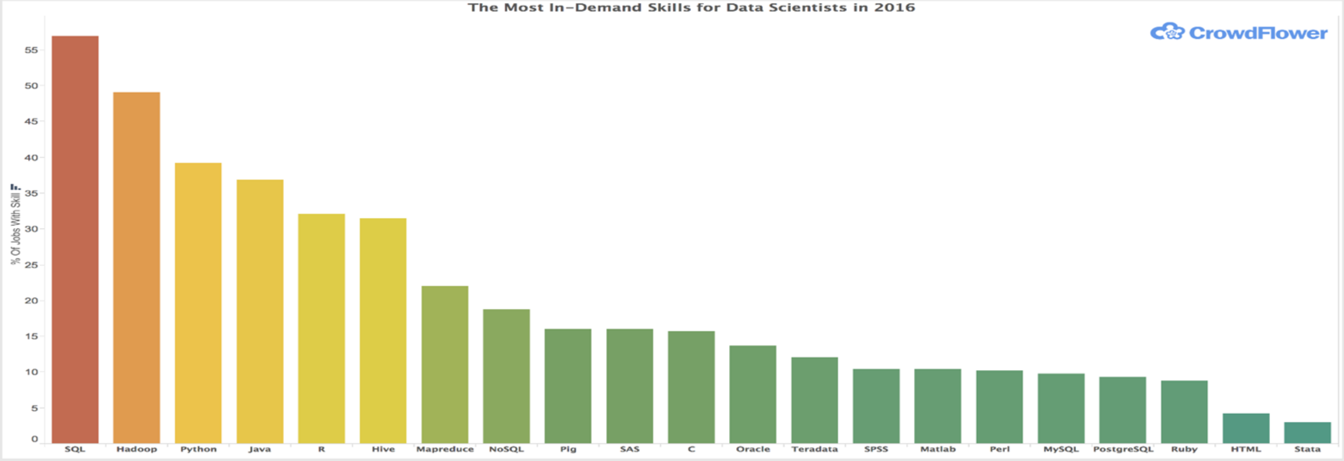
Applications



Data Science Skills Employers Want

Writing SQL Queries & Building Data Pipelines (KDnuggets 2022)

- “Learning how to write robust SQL queries and scheduling them on a workflow management platform like Airflow will make you extremely desirable as a data scientist, hence why it’s point #1.”



https://www.datanami.com/2016/01/07/what-data-science-skills-employers-want-now
https://www.kdnuggets.com/2021/10/11-most-practical-data-science-skills-2022.html

What is Data?

- **Data**: known facts that can be recorded and have *implicit meaning* ...

For example - a student records database:

Item	Type of data	Stored as
Name	String	Character strings?
Birthdate	Date	3 integers?
WAM	Real number	Float number?
…		

Two Types of Data

- Data that is **Unstructured**
  - ➢ No need to pre-define the data
  - ➢ Requires expertise to prepare the data due to its non-formatted nature
  - ➢ Can be a combination of various data
- Data that is **Structured**
  - ➢ Stored with a rigid and strict schema
  - ➢ Can be organized into relational databases

Database Example

- Create a database that manages course enrollment for all UNSW students.
- Things we need (simplified):
  - Information about <u>Students</u>
  - Information about <u>Courses</u>
  - Information about course <u>Selections</u>

File Systems as Data Management?

- **File based system** (strawman):
  - Contains various information on a storage device (hard disk)
  - Files (such as TXT/CSV/EXCEL files, object files, source files)
  - Stores files directly on the device and maybe in directories

STUDENT.csv (name, id, major)

```
"name","id","major"
"Smith","17","IT"
"Amy","8","IT"
```

COURSE.csv (code, name, department)

```
"code","name","department"
"COMP9311","Database Systems","CSE"
"COMP9312","Data Analytics for
Graphs","CSE"
```

SELECTION.csv (student_id, course_code, term)

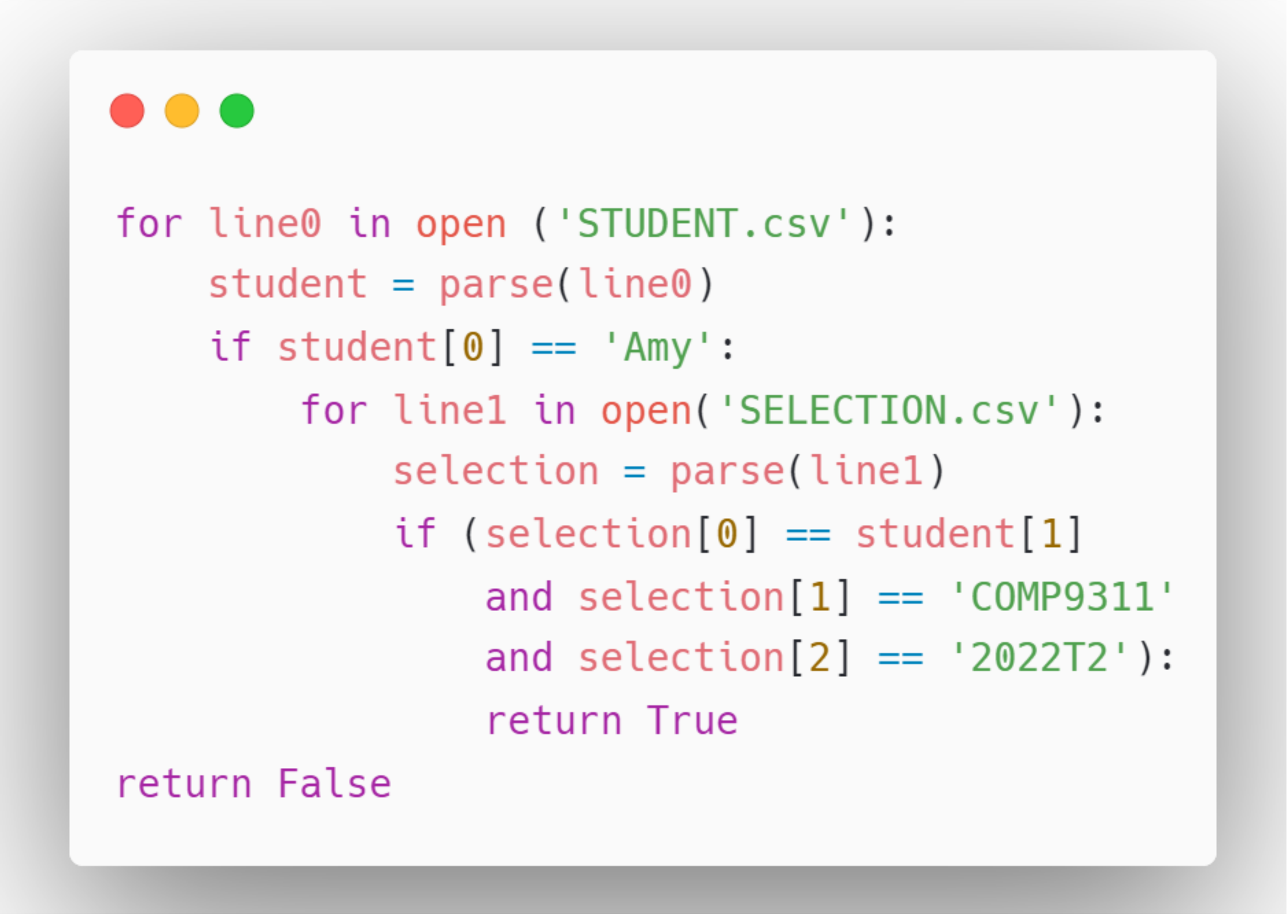
```
"student_id","course_code","term"
"17","COMP9311","2022T2"
"17","COMP9312","2022T2"
"8","COMP9311","2022T2"
```

File Systems as Data Management?

Question: Does Amy select COMP9311 in 2022T2?

File Systems as Data Management?

Question: Does Amy select COMP9311 in 2022T2?



```
for line0 in open ('STUDENT.csv'):
    student = parse(line0)
    if student[0] == 'Amy':
        for line1 in open('SELECTION.csv'):
            selection = parse(line1)
            if (selection[0] == student[1]
                and selection[1] == 'COMP9311'
                and selection[2] == '2022T2'):
                return True
return False
```

Why Database Systems (1)

Drawbacks of using file systems to store data:

- ***Data redundancy and inconsistency***
  - Multiple file formats, duplication of information in different files
- ***Difficulty in accessing data***
  - Would have to write a new program to carry out each new task
- ***Data isolation* — multiple files and formats**
- ***Integrity problems***
  - Integrity constraints (e.g., account balance >= 0) become "buried" in program code rather than being clearly kept and stated
  - Hard to add new constraints or change existing ones

Why Database Systems (2)

Drawbacks of using file systems (cont.)

- ***Atomicity of updates***
  - What is computer crashes?
  - Failures may leave the data in an inconsistent state.
  - Example: Transfer of funds from one account to another should either complete or not happen at all.
- ***Hard to allow concurrent access by multiple users***
  - Uncontrolled concurrent accesses can lead to inconsistencies
    - Example: Two people reading a balance (say 100) and updating it by withdrawing money (say 50 each) at the same time

Database systems offer solutions to all the above problems.

Database Management System (DBMS)

A database management system (**DBMS**) is software that allows applications to store and access information in a database.

DBMS contains:

- Collection of interrelated data
- Set of programs to access the data (i.e., define, create, query, update, and administrate)
- An environment that is both *convenient* and *efficient* to use

Outline

- Course introduction
- Database introduction
- **Database features**

DBMS Features

- Data Independence
- Efficient Data Access
- Data Integrity and Security
- Data Administration
- Concurrent Access and Crash Recovery
- Reduced Application Development Time

What you see is only a tip of the iceberg

Database Management System (DBMS)

Recall Database Applications with DBMS

- Banking: transactions
- Airlines: reservations, schedules
- Universities: registration, grades
- Sales: customers, products, purchases
- Online retailers: order tracking, customized recommendations
- Manufacturing: production, inventory, orders, supply chain
- Human resources: employee records, salaries, tax deductions

Databases touch all aspects of our lives

Database Systems

Frequent Terms

- Data ... defined by the scenario
- Relationships ... amongst data items
- Constraints ... on data and relationships
- Redundancy ... one source for each data item
- Data Manipulation ... declarative, procedural
- Concurrency ... multiple users sharing data
- Transactions ... multiple actions, atomic effect

Summary

- *Data*: known facts that can be recorded and have implicit meaning ...
- *Database*: ... a collection of related data ...
- *Database Management System (DBMS):* ... a collection of programs that enables users to create and maintain a database ...
- *Database System:* ... The database and DBMS together ...

A Little Bit of History

- **Early 1960s:** First general-purpose DBMS, Integrated Data Store, by Charles Bachman (Turing Award)
- **Late 1960s:** IBM developed Information Management System (IMS) DBMS, adopting the hierarchical data model
- **1970s:** Edgar Codd (Turing Award), at IBM, proposed the relational model
- **1980s:** SQL became the standard. Jim Gray (Turing Award) presented the concepts of transaction
- **Late 1980s, 1990s:** ORACLE, DB2 by IBM, and POSTGRES by Michael Stonebraker (Turing Award). Data warehouse.
- **1998+:** NoSQL
- **Current:** Big data & large distributed data processing

Database requirements

Database Systems give you the ability to…

- *Define a database*
  - specifying the data items to be stored and their types,
- *Construct a database*
  - loading the data items and storing them on some storage medium,
- *Manipulate a database*
  - querying - i.e. retrieving relevant data,
  - updating - i.e. adding, deleting or modifying data items
- *Obtain Usage Reports*

Database requirements (2)

Basic Expectations:

- *Timely - e.g., an airline database (fast response), a CAD system (must be interactive).*
- *Modifiable - must be able to be extended or reorganised, e.g., to cope with new laws, requirements, business conditions.*
- *Robust - e.g., power failure during an update - must be able to recover to a consistent state.*
- *Multi-user - e.g., trading system.*
- *Secure* - different classes of users may need different levels of access,
- *No redundancy*

Database Users

- Database Administrator (DBA)
  - Design of the conceptual and physical schemas
  - Security and authorization
  - Data availability and recovery from failures
  - Database tuning
- Application Programmer
  - Implement the specific requirements
  - E.g., Web Developer
- End User

Data Model

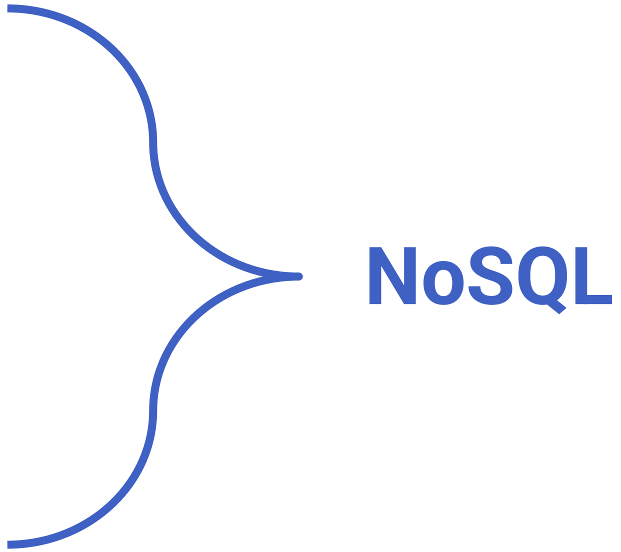
Data model: concepts used to describe the allowed structure of a database. i.e., the structure of the meta-data.

Levels of Data Models:

- **High-level or conceptual** (e.g. ER model – concerns entities, attributes and relationships)
- **Implementation or record-based** (e.g. Relational, Network, Hierarchical – that can be used to immediately derive a physical implementation)
- **Low-level or physical** (concerns record formats, access paths etc)

Types of DBMS

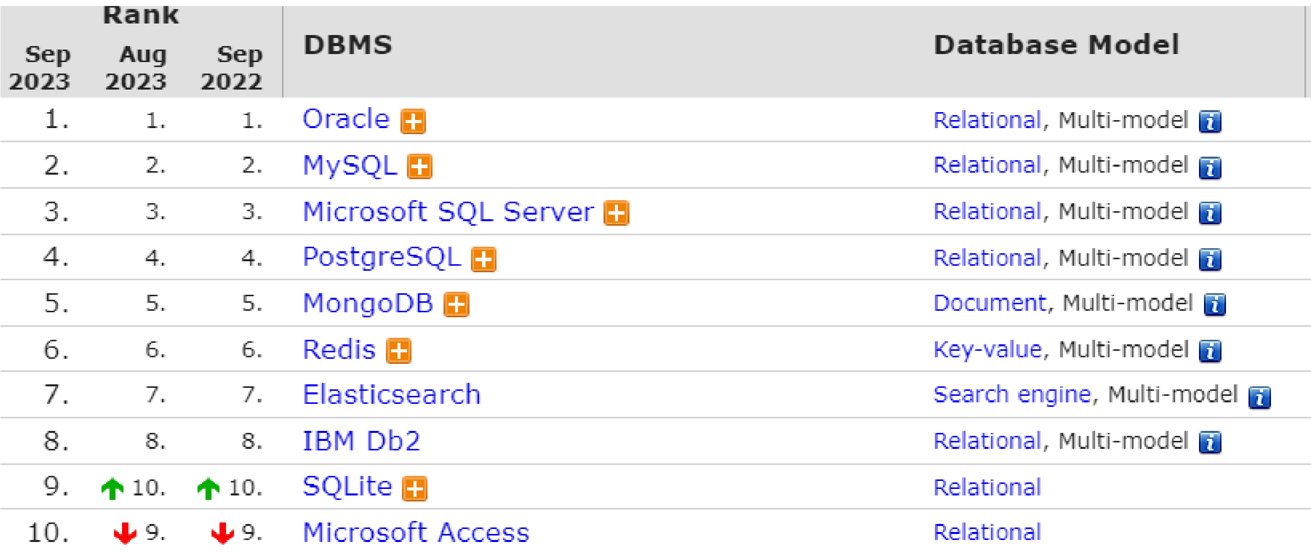
- Relational
- Key/Value
- Graph
- Document
- Column-family



NoSQL

Top Database Management Systems

1. *Oracle* (Relational DBMS)
2. *MySQL* (Relational DBMS)
3. *Microsoft SQL Server* (Relational DBMS)
4. *PostgreSQL* (Relational DBMS)
5. *MongoDB* (Document Store)
6. Redis (Key-value Store)
7. Elasticsearch (Search Engine)
8. IBM DB2 (Relational DBMS)
9. SQLite (Relational DBMS)
10. Microsoft Access (Relational DBMS)



Rank			DBMS	Database Model
Sep 2023	Aug 2023	Sep 2022		
1.	1.	1.	Oracle	Relational, Multi-model
2.	2.	2.	MySQL	Relational, Multi-model
3.	3.	3.	Microsoft SQL Server	Relational, Multi-model
4.	4.	4.	PostgreSQL	Relational, Multi-model
5.	5.	5.	MongoDB	Document, Multi-model
6.	6.	6.	Redis	Key-value, Multi-model
7.	7.	7.	Elasticsearch	Search engine, Multi-model
8.	8.	8.	IBM Db2	Relational, Multi-model
9.	↑ 10.	↑ 10.	SQLite	Relational
10.	↓ 9.	↓ 9.	Microsoft Access	Relational

Source: http://db-engines.com/en/ranking

Data Model Concepts

Database Schema: a *formalism* of the data model, the *structural description* of what information will database holds.

Database Instance *(or State): any combination of actual information populated* in the database at a particular time.

Workflow:

- We define a database by specifying its schema.
- The state is then an empty instance of the schema.
- To create the initial instance we load in data.
- After this, each change in state is an update to the instance.

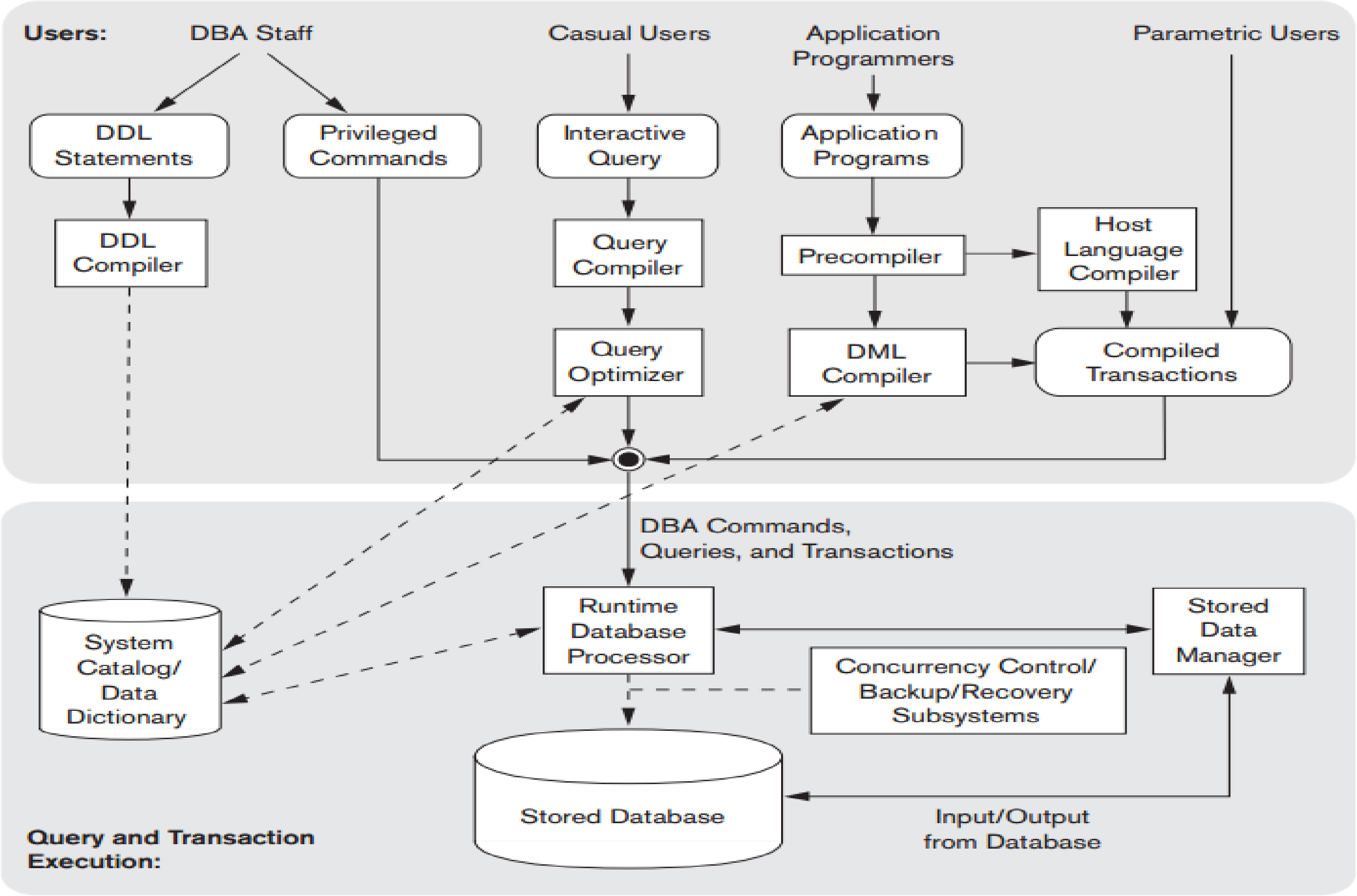
Design a Database

- **Conceptual Design**
  - Requirements can be represented and manipulated using some computerized tools so that it can be easily maintained, modified, and transformed into a database implementation
- **Logical Design**
  - Translated by conceptual design that can be expressed in a data model implemented in a DBMS
- **Physical Design**
  - Further specifications are provided for storing and accessing the database

Database Languages

- ***Data definition language (DDL):*** used to define the conceptual schema.
- ***Data manipulation languages (DML):*** let users write requests to retrieve and manipulate data, as well as other tasks relating to data manipulation.
  - *Non-procedural DML* (e.g., SQL, common for casual users)
    - interactive and/or embedded
    - set at a time/ set oriented.
  - *Procedural DML* (also covered in this course)
    - embedded in a general purpose language,
    - record at a time

Database System



Component modules of a DBMS and their interactions.

In Conclusion

Hopefully, you now know…

- course structure,
- who to contact (where to seek help before emailing me),
- how you’re assessed and scored,
- the database applications around you,
- what goes on in databases (and is interested),

Next Lecture: Data Modelling, ER Diagram