

# Introduction to Databases

## 《数据库引论》



# Lecture 1: Introduction to Database Systems

## 第1讲：数据库系统简介

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# Outline of the Course

- ☞ **Part 0: Overview**
  - Lect. 1 (Feb. 29) - Ch1: Introduction
- **Part 1 Relational Databases**
  - Lect. 2 (Mar. 7) - Ch2: Relational model (data model, relational algebra)
  - Lect. 3 (Mar. 14) - Ch3&4: SQL (Introduction and intermediate)
  - Lect. 4 (Mar. 21) - Ch5: Advanced SQL
- **Part 2 Database Design**
  - Lect. 5 (Mar. 28) - Ch6: Database design based on E-R model
  - **Apr. 4 (Tomb-Sweeping Day): no course**
  - Lect. 6 (Apr. 11) - Ch7: Relational database design
- **Midterm exam: Apr. 18**
- **Part 3 Data Storage & Indexing**
  - Lect. 7 (Apr. 25) - Ch12/13: Storage systems & structures
  - Lect. 8 (May 3 -> Apr. 28) - Ch14: Indexing
- **Part 4 Query Processing & Optimization**
  - Lect. 9 (May 10) - Ch15: Query processing
  - Lect. 10 (May 17) - Ch16: Query optimization
- **Part 5 Transaction Management**
  - Lect. 11 (May 24) - Ch17: Transactions
  - Lect. 12 (May 31) - Ch18: Concurrency control
  - Lect. 13 (Jun. 7) - Ch19: Recovery system
- **Part 6 DB Systems & Course Review**
  - Lect. 14 (Jun. 14)

**Final exam: 13:00-15:00, Jun. 26**

# Outline

- Data, information, knowledge and beyond
- Database system
- Data view
- DB languages
- DB design
- DB engine
- Database architecture
- DB user and administrator
- History of DB
- Future directions

# Outline

## ☞ Data, information, knowledge and beyond

- Database system
- Data view
- DB languages
- DB design
- DB engine
- Database architecture
- DB user and administrator
- History of DB
- Future directions

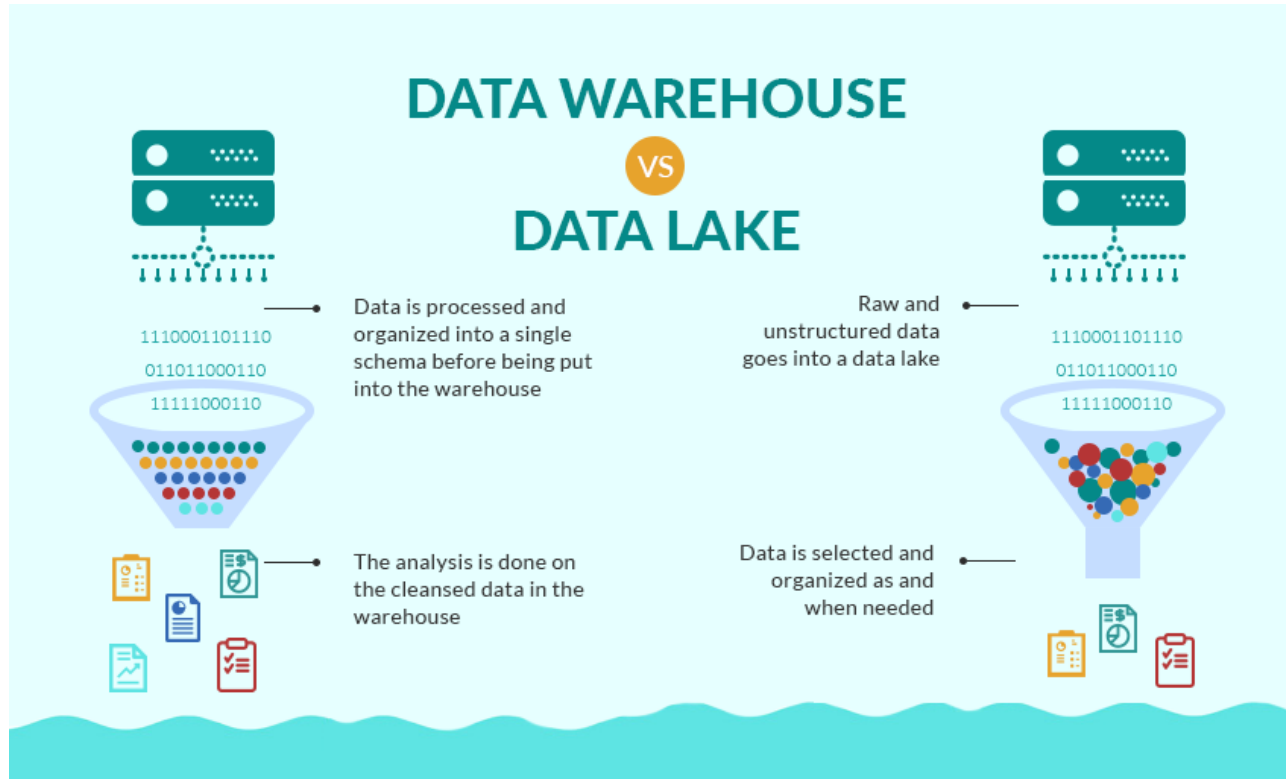
# Data

- **Data** is a set of values of qualitative or quantitative variables.
  - The results of describing or quantifying anything
  - 描述/量化学事物的符号/数字记录
- Data is **collected, stored** and **analyzed**. It can be **visualized** using graphs, images and other analysis tools.
- Data has been described as the new oil of **Digital Economy** (数字经济).
- **Data, information, knowledge, intelligence**, and **wisdom** are closely related concepts, but each has its own role in relation to the others, and each term has its own meaning.

# Data related concepts and technologies

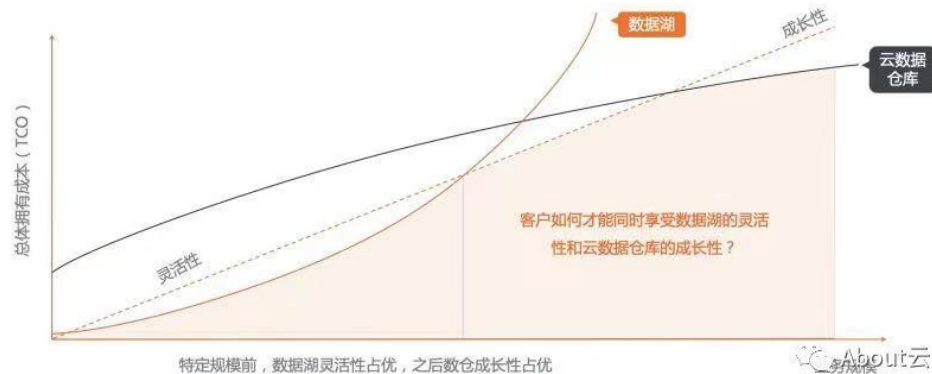
- **Data related concepts and technologies**
  - Data acquisition, Data modeling, Data structure
  - Data integrity, Data maintenance, Data management
  - Data processing, Data analysis, Data mining, Data visualization
  - Data publication, Data protection, Data privacy
  - Big Data, Data science
- **Data resources**
  - Experimental / biological / environmental / transportation ... data
- Data set, Datasheet, **Database**, Data mart (数据集市), Data warehouse (数据仓库), Data lake (数据湖), Data lakehouse (数据湖仓), Data middle office (数据中台)

# Data warehouse vs. Data lake



# Data warehouse vs. Data lake

	DATA LAKE	DATA WAREHOUSE
Structure	Raw	Processed
Purpose	Not Yet Determined	Pre-determined
Use Case	Data Scientists	Business Users
Accessibility	Highly Accessible and Quick to Update	Complicated and Costly to Change



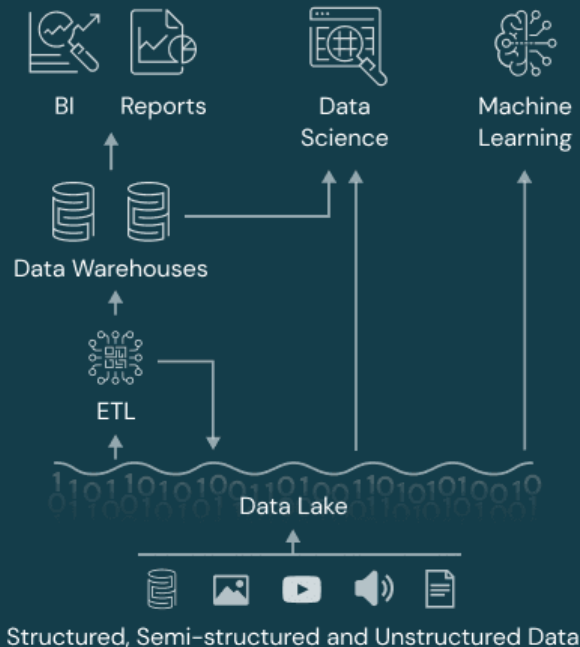


# Data warehouse, Data lake, Lakehouse

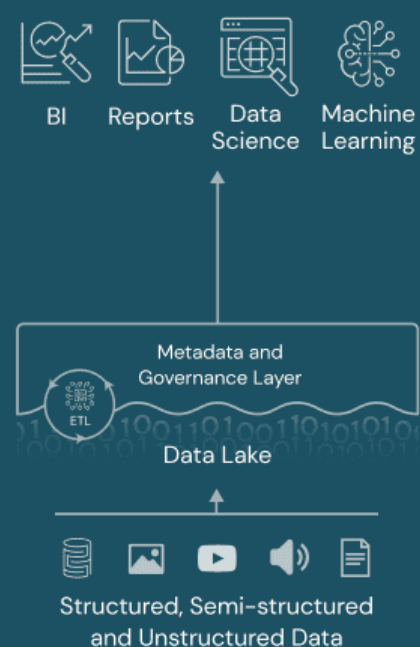
## Data Warehouse



## Data Lake



## Data Lakehouse



# Big Data

- It's said that the term "Big data" in its current use was coined by *Roger Magoulas @ O'Reilly Media*
- There is not a consensus as to how to define big data

“Big data exceeds the reach of commonly used hardware environments and software tools to capture, manage, and process it with in a tolerable elapsed time for its user population.”

- *Teradata Magazine article, 2011*

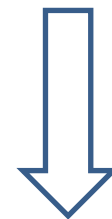
“Big data refers to data sets whose size is beyond the ability of typical database software tools to capture, store, manage and analyze.”

- *The McKinsey Global Institute, 2011*

# The Vs of Big Data

- **3Vs model**
  - high-volume, high-velocity, and/or high-variety
    - Gartner (2012)
- **4Vs models**
  - Volume, velocity, variety and **virtual**
    - Courtney Lambert (2012)
  - Volume, velocity, variety and **veracity**
    - IBM (2012)
  - Volume, velocity, variety and **value**
    - DataStax (2012)
- **5Vs model**
  - **Volume, velocity, variety, veracity and value**

**Big**



**Complete**

# Big Data: A Joke

某比萨店的电话铃响了，客服人员拿起电话。

客服：XXX比萨店。您好，请问有什么需要我为您服务？

顾客：你好，我想要一份.....

客服：先生，烦请先把您的会员卡号告诉我。

顾客：16846146\*\*\*。

客服：陈先生，您好！**您是住在泉州路一号12楼120x室**，请问您想要点什么？

顾客：我想要一个海鲜比萨.....

客服：陈先生，海鲜比萨不适合您。

顾客：为什么？

客服：**根据您的医疗记录，您的血压和胆固醇都偏高。**

顾客：那你们有什么可以推荐的？

客服：您可以试试我们的低脂健康比萨。

顾客：你怎么知道我会喜欢吃这种的？

客服：**您上星期一在中央图书馆借了一本《低脂健康食谱》。**

顾客：好。那我要一个家庭特大号比萨，要付多少钱？

客服：**99元，这个足够您一家六口吃了。但您母亲应该少吃，她上个月刚刚做了心脏搭桥手术，还处在恢复期。**

顾客：那可以刷卡吗？

客服：陈先生，对不起。请您付现款，因为**您的信用卡已经刷爆了，您现在还欠银行4807元，而且还不包括房贷利息**

顾客：那我先去附近的提款机提款。

客服：陈先生，**根据您的记录，您已经超过今日提款限额。**

顾客：算了，你们直接把比萨送我家吧，家里有现金。你们多久会送到？

客服：大约30分钟。如果您不想等，可以自己骑车来。

顾客：为什么？

客服：**根据我们全球定位系统的车辆行驶自动跟踪系统记录。您登记有一辆车号为XX-748的摩托车，而目前您正在解放路东段华联商场右侧骑着这辆摩托车。**

顾客当即晕倒.....

家庭住址

医疗记录

借阅记录

医疗记录

借贷记录

定位跟踪

# Information & Information Retrieval

- **Information**

- **Data with meaning or semantics**
- Provide the answer to a question of some kind or resolves uncertainty. It is thus **related to data and knowledge**, as data represents values attributed to parameters, and knowledge signifies understanding of real things or abstract concepts.

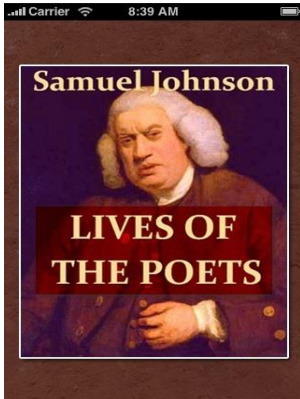
- **Information retrieval (IR)**

- The activity of obtaining information from a collection of information resources. **Searches** can be based on full-text or other content-based indexing.

# Knowledge $\Rightarrow$ knowledge base + inference engine = Expert System

- Knowledge

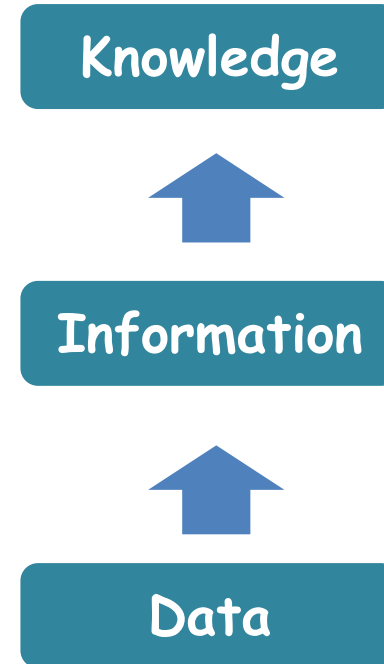
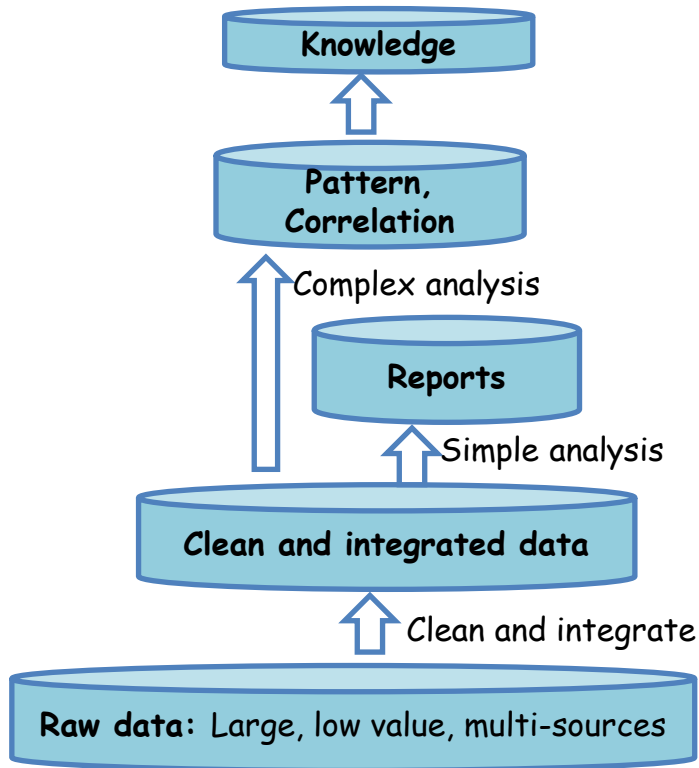
- Information with value
- Familiarity, awareness, or understanding of someone or something, such as facts, information, descriptions, or skills. Knowledge is acquired **through experience or education** by **perceiving, discovering, or learning**.
- In philosophy, the study of knowledge is called **epistemology** (认识论). Theories of knowledge, Communicating knowledge, Situated knowledge, Partial knowledge, Scientific knowledge, Religious meaning of knowledge.



“Knowledge is of two kinds: we know a subject ourselves, or we know where we can find information upon it.”

Samuel Johnson (1709-1784)

# Data, Information and Knowledge



# Intelligence VS. Artificial Intelligence

- The ability to acquire and apply knowledge and skills
- **Intelligence** has been defined in many ways to include the capacity for **logic, understanding, self-awareness, learning, emotional knowledge, reasoning, planning, creativity, and problem solving**. It can be more generally described as the ability to perceive or infer **information**, and to retain it as **knowledge** to be applied towards **adaptive behaviors** within an environment or context.
- **Artificial intelligence (or AI)** is both the intelligence of machines and the branch of computer science which aims to create it, through "**the study and design of intelligent agents**" or "**rational agents**", where an intelligent agent is a system that perceives its environment and takes actions which maximize its chances of success.



# Intelligence vs. Artificial Intelligence

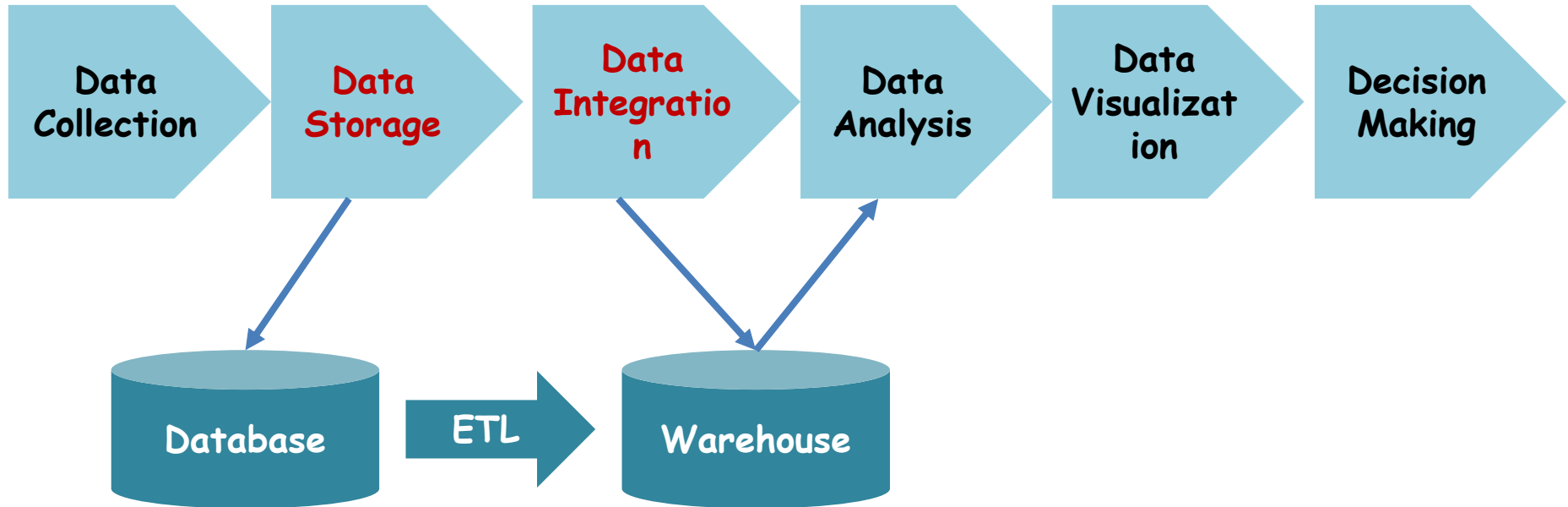
- **General intelligence** or **strong AI**
  - Intelligence like human's intelligence
  - Adaptive to environment, creativity
  - has not yet been achieved, but some great advances have made (e.g. ChatGPT)
- Researchers have been trying to make machines exhibit reasoning, planning, learning, communication, perception, and the ability to move and to manipulate objects, closely simulating human brain.
- DeepMind: AlphaGo, Alphafold2, .....
- OpenAI: ChatGPT/GPT4/5, SORA, .....

# Intelligence vs. Wisdom

- Intelligence is the ability to learn and acquire and apply knowledge
  - deals more with practical facts.
- Wisdom is intelligence garnered through experience. We learn through our experiences and we use this knowledge to make decisions
  - based on right and wrong
- Wisdom is high-level intelligence (?)
- Wisdom = IQ+EQ (?)

- **Data Mining**: finding hidden, nontrivial, previously unknown and useful knowledge from massive data
  - Rules/patterns
- **Data Warehousing**
  - The process of building data warehouse
- **Query Processing**
  - Extracting desirable data from databases
- **Information Retrieval**
  - Searching the matching information from unstructured textual data

# Data Processing Flow



ETL: Extract, Transform and Load

# Outline

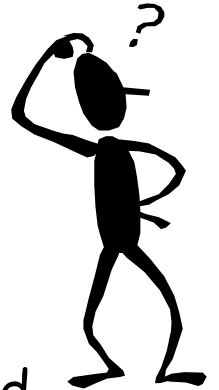
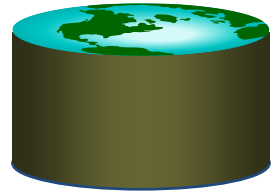
- Data, information, knowledge and beyond

-  Database system

- Data view
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# What Is a Database

- **An integrated collection of data**
  - The data is **structured** and **interrelated**
  - The data is **integrated**
- **Model real-world enterprises or organizations**
  - **Entities** (e.g., students, courses)
  - **Relationships** (e.g. Li is taking Database and OS )
- **Databases touch various aspects of our lives**
  - People interact with database from indirect way (printed report) to direct way (teller machine)



# Database Applications

- **Various applications**
  - Banking: all transactions
  - Ticket systems: 12306
  - E-commerce platforms: Toubao, Jingdong, .....
  - Airlines: reservations, schedules
  - Universities: registration, grades, students
  - Sales: customers, products, purchases
  - Online retailers: order tracking, customized recommendations
  - Manufacturing: production, inventory, orders, supply chain
  - Human resources: employee records, salaries, tax deductions
  - .....

# Example: University Database

- **Application scenarios**
  - Add new students, instructors and courses
  - Register students for courses, and generate class rosters (名单)
  - Assign grades to students, calculate grade point averages (GPA) and generate transcripts
- In the early days, **applications** were built directly on top of file systems



# Drawbacks of using File Systems to Store Data

- **Data redundancy (冗余) and inconsistency (不一致)**
  - Multiple file formats (different programmers/languages/structures), duplication of information in different files
- **Difficulty in accessing data**
  - Need to write a new program to carry out each new task
- **Data isolation (隔离)**
  - Multiple files and formats
- **Integrity (完整性) problems**
  - **Integrity constraints** (e.g., account balance  $> 0$ ) become "buried" in program code rather than being stated explicitly
  - Hard to add new constraints or change existing ones

# Drawbacks of using File Systems to Store Data

- **Atomicity (原子性) of updates**
  - Failures may leave database in an **inconsistent state** with **partial updates carried out**
    - E.g., transfer of funds from one account to another should either complete or not happen at all
- **Concurrent access (并发访问) by multiple users**
  - Concurrent access needed for better performance
  - Uncontrolled concurrent accesses can lead to **inconsistencies**
    - E.g., two people reading a balance (say 100) and updating it by withdrawing money (say 50 each) at the same time
- **Security (安全) problems**
  - Hard to provide user access to some, but not all, data

# Database Management System (DBMS)

- **DBMS**
  - A software package designed to store and manage databases
- **Functions of DBMS**
  - **Manages** a large amount of data
  - Supports **efficient and concurrent access** to a large amount of data
  - Supports **secure, atomic** access to a large amount of data: two people editing the same file - last to write "wins"
- **Advantages of DBMS**
  - Data independence and efficient access
  - Reduce application development time
  - Data integrity and security
  - Uniform data administration
  - Concurrent access
  - Recovery from crashes

# Is a File System a DBMS?

- **Experiment 1:**

- You and your partner are editing the same file.
- You both save it at the same time.
- Whose changes survive?

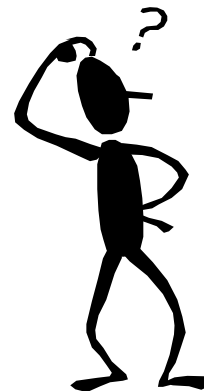
A) Yours

B) Partner's

C) Both

D) Neither

E) ???



- **Experiment 2:**

- You're updating a file.
- The power goes out.
- Which of your changes cannot survive?

A) All

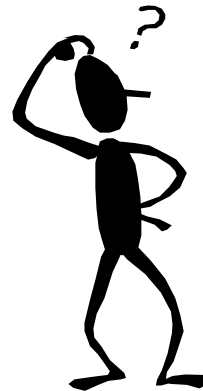
B) None

C) All since last save

D) ???

# Is a Traditional IR System a DBMS?

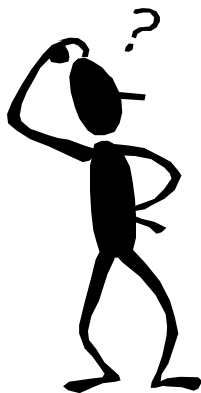
- Traditional **IR (Information Retrieval, 信息检索)** system
  - Mainly for data retrieval, not data update
  - Store/manage **free structured or semi-structured** document
  - Support **semantic-oriented matching (语义匹配)**
  - Consider no data consistency, and concurrency is easy to be implemented



- **DBMS**
  - Support data **access and update**
  - Store and manage **structured** data (**RDBMS**)
  - Require **declarative (陈述性)** query language support
  - Support **data consistency, atomic transaction, concurrency control** and **failure recovery**

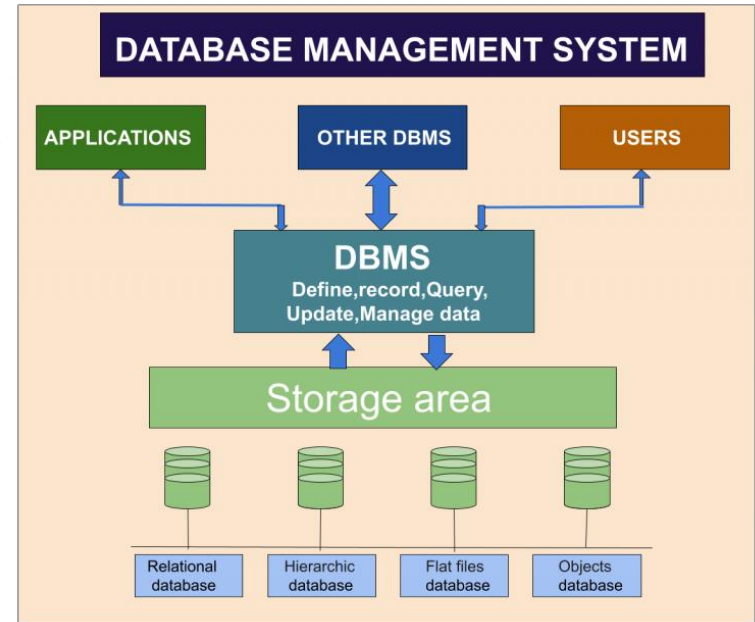
# Is Web Search Engine a DBMS?

- **Keyword-based search for pages**
- Data is mostly unstructured and untyped
- **Search only**
  - can't modify the data
  - can't get summaries (概括) , complex combinations of data
- Few guarantees provided for freshness of data, consistency across data items, fault tolerance, etc.
- Web sites (e.g., e-commerce 电子商务) typically have a DBMS in the backend to provide these functions



# Database Systems

- A Database System (DBS) contains the following components
  - Hardware platform (PC, Workstation, Cluster, Mainframe, etc.)
  - DBMS
  - A (number of) database(s)
  - Human interface that is both convenient and efficient to use




# What's the Intellectual Content?

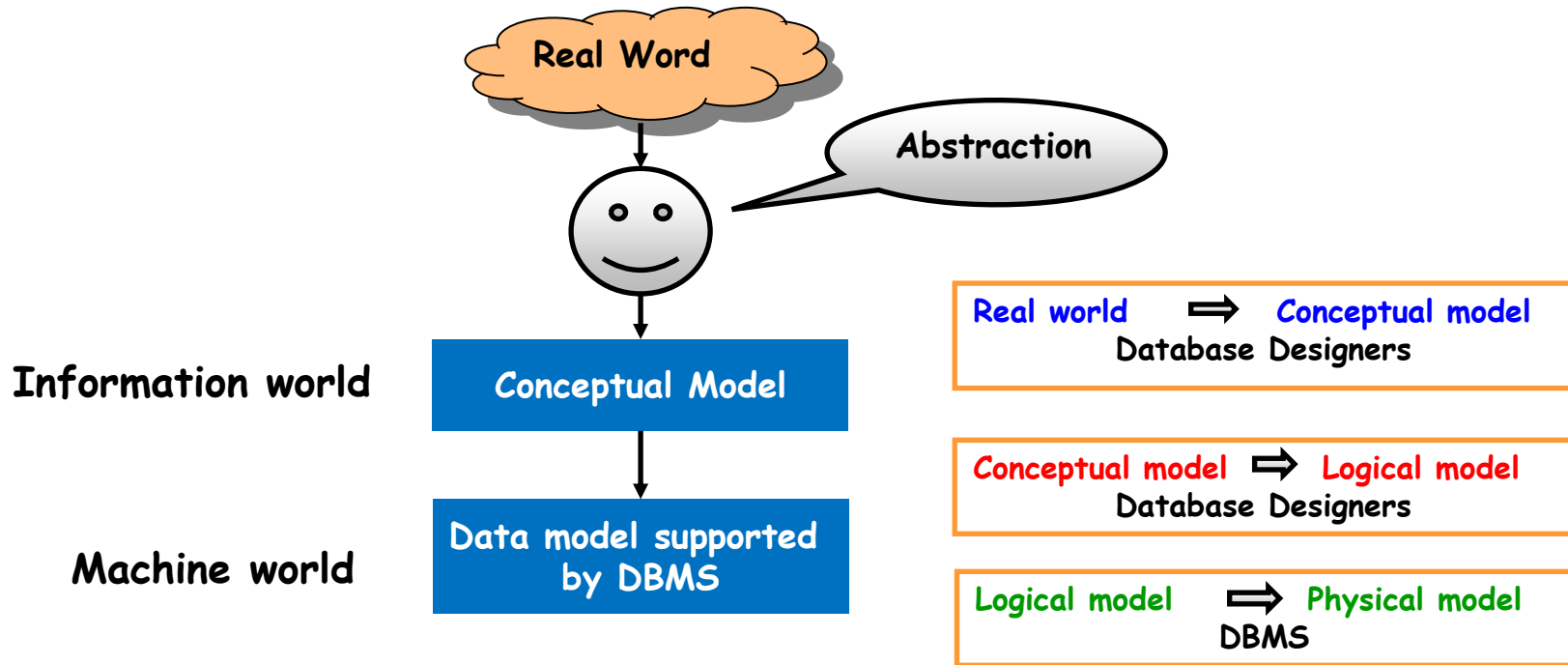
- Representing information
  - data modeling
- Languages and systems for querying data
  - complex queries with real semantics over massive data sets
- Concurrency control for data manipulation
  - controlling concurrent access
  - ensuring transactional semantics
- Reliable data storage
  - maintain data semantics even if you pull the plug



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-  **Data view**
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# Data Abstraction



# Levels of Abstraction

- **Physical level**

- Describe **how** a **record** is **stored** on storage devices.

- **Logical level**

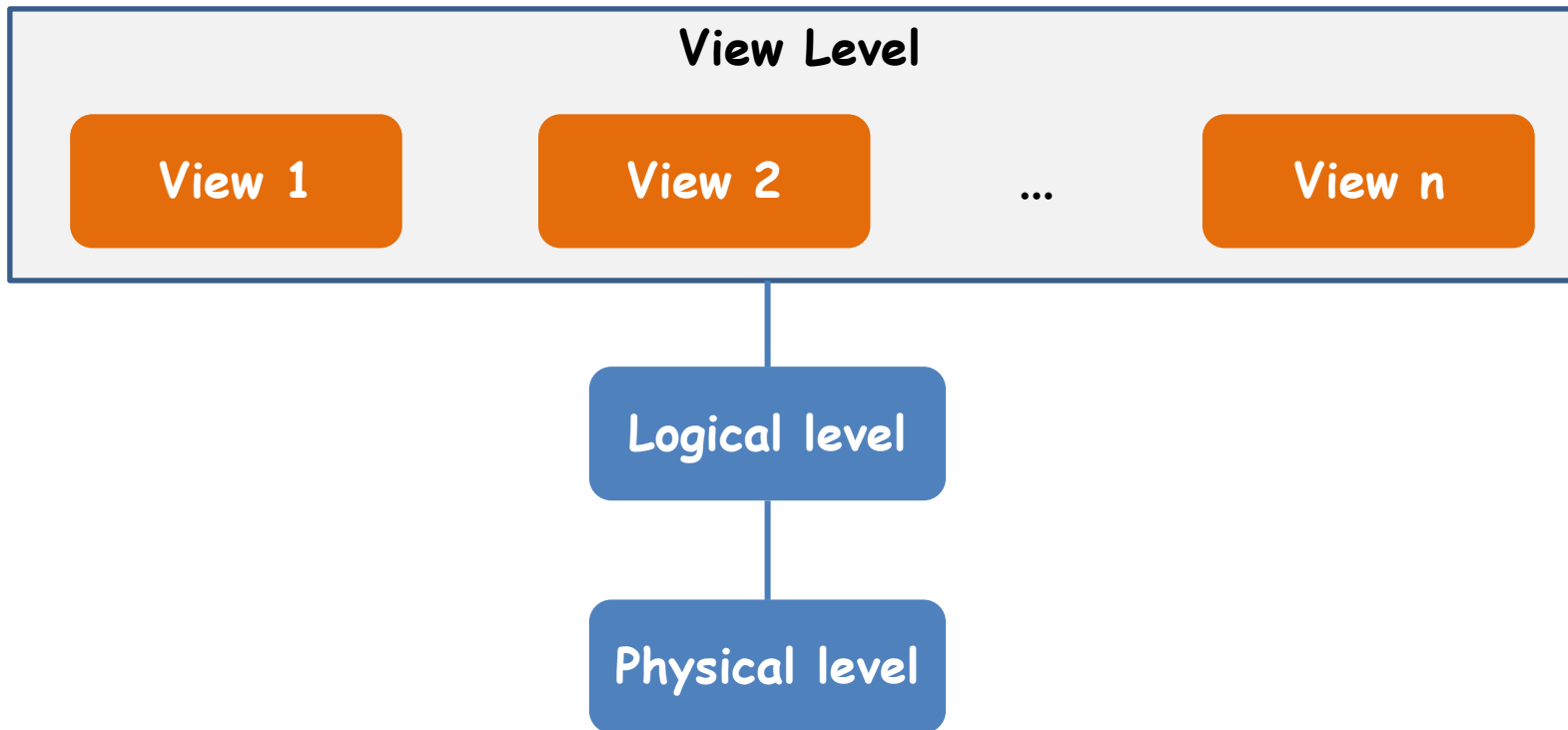
- Describe **what** data stored in database, and the **relationships** among the data.
- Although implementation of the simple structures at the logical level may involve complex physical-level structures, the user of the logical level does not need to be aware of this complexity. This is referred to as **physical data independence**.

```
type customer = record  
    customer_id : string;  
    customer_name : string;  
    customer_street : string;  
    customer_city : integer;  
end;
```

- **View level**

- Many users of the database system do not need all this information; instead, they need to **access only a part of the database**. The view level of **abstraction** simplifies their interaction with the system.
- Views can also **hide information** (such as an employee's salary) for security purposes.

# View of Data



# Instances and Schemas

- Similar to **variables** and **types** in programming languages
- **Schema** (模式): the **logical structure** of the database
  - E.g., the database consists of information about a set of customers and accounts, and the relationship between them
  - Analogous to type information of a variable in a program
    - **Physical schema** (物理模式): database design at the **physical level**
    - **Logical schema** (逻辑模式): database design at the **logical level**
    - **External schema** (外模式): user defined schema at the **app level (view level)**
- **Instance** (实例): the actual content of the database **at a particular point of time**, analogous to the value of a variable

# Instances and Schemas

- **Schema** - the logical structure of the database
  - Physical schema: internal schema, storage schema
  - Logical schema: schema
  - External schema: user's schema, subschema
- **Physical data independence** - the ability to modify the physical schema without changing the logical schema
  - In general, the interfaces between the various levels and components should be well defined so that changes in some parts do not seriously influence others
- **Logical data independence** - the ability to modify the logical schema without changing the external schema

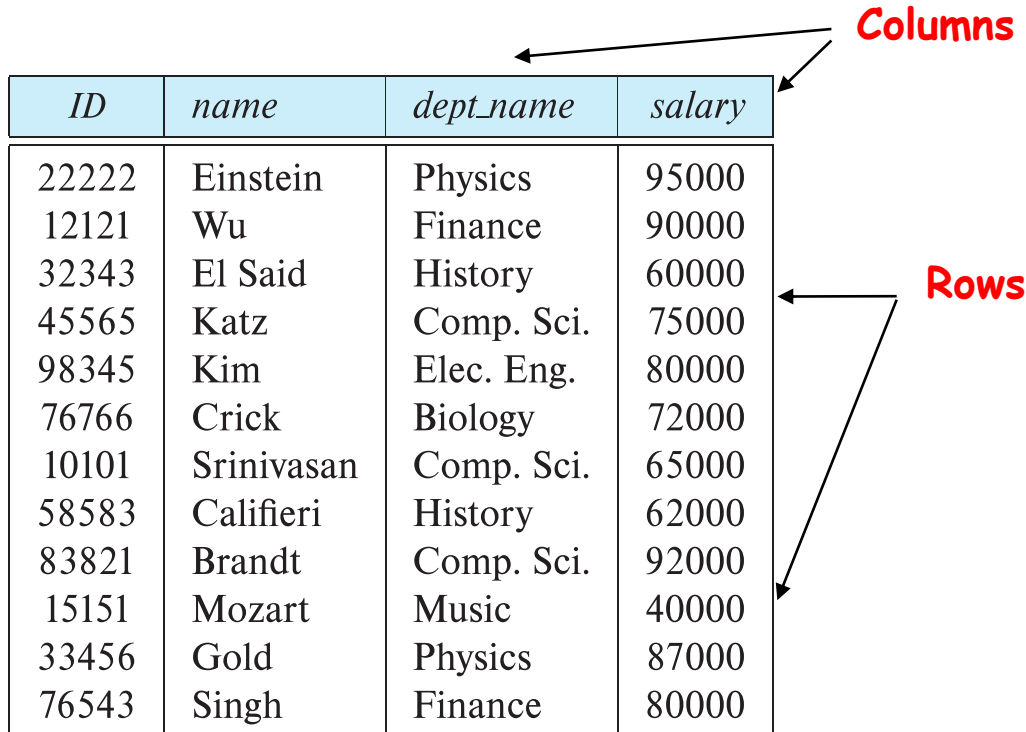
# Data Models

A collection of **tools** for describing data structures, data relationships, data semantics, and data constraints

- **Relational model**
  - Tables as relations to represent data and their relationships
  - Record-based model
- **Entity-Relationship data model** (mainly for database design)
  - Entity-relationship (E-R) data model
- **Object-based data models (Object-oriented/Object-relational)**
  - Extending the E-R model with notions of encapsulation, methods(functions), and object identity
- **Semi-structured data model (JSON, XML)**
- **Other older models:**
  - Network model (e.g. Honeywell IDS)
  - Hierarchical model (e.g. IBM IMS)

# Relational Model

- Example of tabular data in the relational model



The diagram shows a table with four columns and ten rows. An arrow labeled "Columns" points to the top row, and an arrow labeled "Rows" points to the right side of the table.

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
76766	Crick	Biology	72000
10101	Srinivasan	Comp. Sci.	65000
58583	Califieri	History	62000
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

(a) The *instructor* table



# A Sample of Relational Database

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
22222	Einstein	Physics	95000
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58583	Califieri	History	62000
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

(a) The *instructor* table

<i>dept_name</i>	<i>building</i>	<i>budget</i>
Comp. Sci.	Taylor	100000
Biology	Watson	90000
Elec. Eng.	Taylor	85000
Music	Packard	80000
Finance	Painter	120000
History	Painter	50000
Physics	Watson	70000

(b) The *department* table

# Object-Relational Data Models

- Extend the relational data model by including
  - Inheritance (继承)/ encapsulation (封装) /methods(functions) /object identity
- Allow attributes of tuples to have **complex types**, including non-atomic values such as **nested relations**
- Preserve relational foundations, in particular the declarative access to data, while extending modeling power
- Provide **upward compatibility** (向上兼容) with existing relational languages

# XML: eXtensible Markup Language


- Defined by WWW Consortium (W3C, 万维网联盟)
- Originally intended as a document markup language not a database language
- The ability to specify **new tags**, and to create **nested tag structures** made XML a great way to exchange data, not just documents
- XML has become the basis for various data interchange formats
- A wide variety of tools is available for parsing, browsing and querying XML documents/data

# XML: An Example

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<CDLIST>
  <CD artist="Yung Jo Yee, Joey">
    <TITLE>Ten Most Wanted</TITLE>
    <RELEASE>Feb 26, 2006</RELEASE>
    <PRICE>$20</PRICE>
  </CD>
  <CD artist="Twins">
    <TITLE>The Missing Piece</TITLE>
    <RELEASE>Feb 20, 2006</RELEASE>
    <PRICE>$10</PRICE>
  </CD>
  <CD artist="Twins">
    <TITLE>2006 Concert Live</TITLE>
    <RELEASE>Feb 20, 2006</RELEASE>
    <PRICE>$10</PRICE>
  </CD>
  <CD artist="Justin">
    <TITLE>No Protection</TITLE>
    <RELEASE>March 24, 2006</RELEASE>
    <PRICE>$15</PRICE>
  </CD>
</CDLIST>
```

Info about one CD

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- History of DB
- Future directions

# Database Language

- A database system provides a **data-definition language (DDL)** to specify the database schema and a **data-manipulation language (DML)** to express database queries and updates.
- **Data-definition language (DDL, 数据定义语言)**
  - Specify the database **schema**
  - SQL provides a rich DDL that allows one to define **tables, integrity constraints, assertions**, etc.
- **Data-manipulation language (DML, 数据操纵语言)**
  - Express database **queries** and **updates**

# Data Definition Language (DDL)

- Defining the database **schema**
  - Example: 

```
create table department (  
    dept_name    char(20),  
    building     char(15)  
    budget       numeric(12,2));
```
- DDL compiler generates **a set of tables** stored in a **data dictionary**
- **Data dictionary** contains **metadata** (i.e., data about data)
  - Database **schema**
  - Data **storage** and **definition** language
    - Specifies the storage structure and access methods
  - **Consistency constraints**
    - Domain constraints
    - Referential integrity (references constraint in SQL)
    - Assertions
    - Authorization

# Data Manipulation Language (DML)

- DML is for **accessing and manipulating** the data organized by the appropriate data model
  - DML also known as query language
  - **Retrieval/ Insertion/ Deletion/ Modification**
- Two classes of languages
  - **Procedural** - user specifies what data is required and how to get those data
  - **Nonprocedural** (**Declarative**, 陈述性) - user specifies what data is required without specifying how to get those data
- **SQL** is the most widely used **non-procedural** query language




# SQL (Structured Query Language)

- **SQL**: widely used **non-procedural** language
  - E.g., find all instructors in the department of History

```
select instructor.name
from instructor
where instructor.dept_name = 'History'
```
  - E.g., find the IDs of all instructors from those departments with a budget larger than 95000

```
select instructor.ID
from instructor, department
where instructor.dept_name = department.dept_name and
department.budget > 95000
```
- Application programs generally access databases through one of
  - Language extensions to allow **embedded SQL**
  - Application program **interface** (e.g., **ODBC/JDBC**) which allow SQL queries to be sent to a database

# Outline

- Data, information, knowledge and beyond
- Database system
- Data view
- DB languages
-  **DB design**
- DB engine
- Database architecture
- DB user and administrator
- History of DB
- Future directions

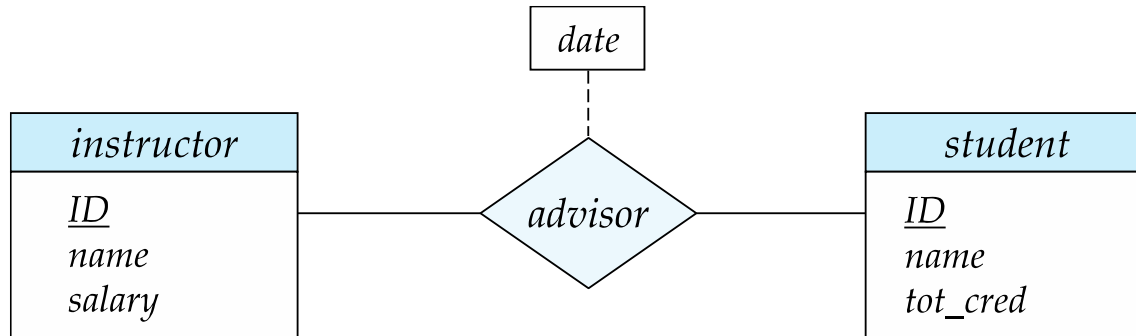
# Database Design

The process of designing the structure of the database:

- **Conceptual design**
  - Decide what should be covered and their relations
  - Deciding on the database conceptual schema via ER model
  - **Business decision** - What attributes should we record in the database?
- **Logical design** - Decide the database schema, find a “good” collection of relation schemas.
  - **Computer science decision** - What relation schemas should we have and how should the attributes be distributed among the various relation schemas?
    - Employ a set of algorithms (collectively known as **normalization**) that takes as input the set of all attributes and generates a set of tables
- **Physical design** - Decide the physical layout of the database

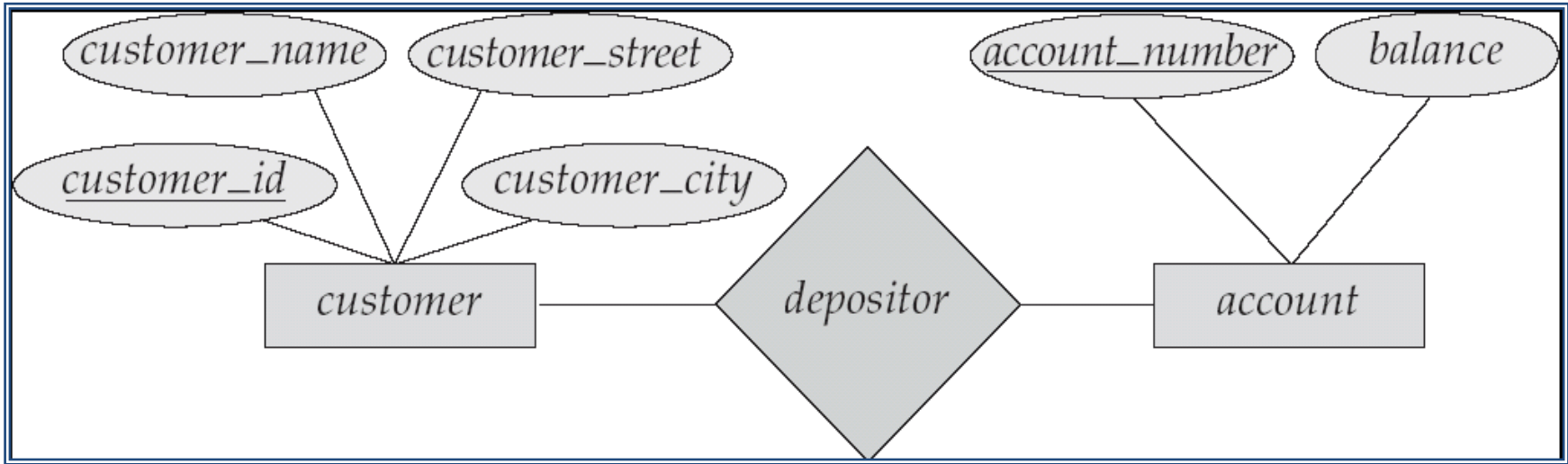
# Entity-Relationship Model

- Model an enterprise as a collection of **entities** and **relationships**
  - **Entity**: a "thing" or "object" in the enterprise that is distinguishable from other objects
    - Described by a set of attributes
  - **Relationship** (diamond): an association among several entities



# The Entity-Relationship Model

- Represented diagrammatically by an *entity-relationship diagram*:



# Relational Model

- Example of tabular data in the relational model

Attributes



Customer-id	customer-name	customer-street	customer-city	account-number
192-83-7465	Johnson	Alma	Palo Alto	A-101
019-28-3746	Smith	North	Rye	A-215
192-83-7465	Johnson	Alma	Palo Alto	A-201
321-12-3123	Jones	Main	Harrison	A-217
019-28-3746	Smith	North	Rye	A-201

# A Sample Relational Database



<i>customer-id</i>	<i>customer-name</i>	<i>customer-street</i>	<i>customer-city</i>
192-83-7465	Johnson	12 Alma St.	Palo Alto
019-28-3746	Smith	4 North St.	Rye
677-89-9011	Hayes	3 Main St.	Harrison
182-73-6091	Turner	123 Putnam Ave.	Stamford
321-12-3123	Jones	100 Main St.	Harrison
336-66-9999	Lindsay	175 Park Ave.	Pittsfield
019-28-3746	Smith	72 North St.	Rye

(a) The *customer* table

<i>account-number</i>	<i>balance</i>
A-101	500
A-215	700
A-102	400
A-305	350
A-201	900
A-217	750
A-222	700

(b) The *account* table

<i>customer-id</i>	<i>account-number</i>
192-83-7465	A-101
192-83-7465	A-201
019-28-3746	A-215
677-89-9011	A-102
182-73-6091	A-305
321-12-3123	A-217
336-66-9999	A-222
019-28-3746	A-201

(c) The *depositor* table

# Data Manipulation Language

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
76766	Crick	Biology	72000
10101	Srinivasan	Comp. Sci.	65000
58583	Califieri	History	62000
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

(a) The *instructor* table

<i>dept_name</i>	<i>building</i>	<i>budget</i>
Comp. Sci.	Taylor	100000
Biology	Watson	90000
Elec. Eng.	Taylor	85000
Music	Packard	80000
Finance	Painter	120000
History	Painter	50000
Physics	Watson	70000


(b) The *department* table

```
select instructor.name  
from instructor  
where instructor.dept_name="History";
```

```
select instructor.ID, department.dept_name  
from instructor, department  
where instructor.dept_name=department.dept_name and  
department.budget > 95000;
```



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# Database engine

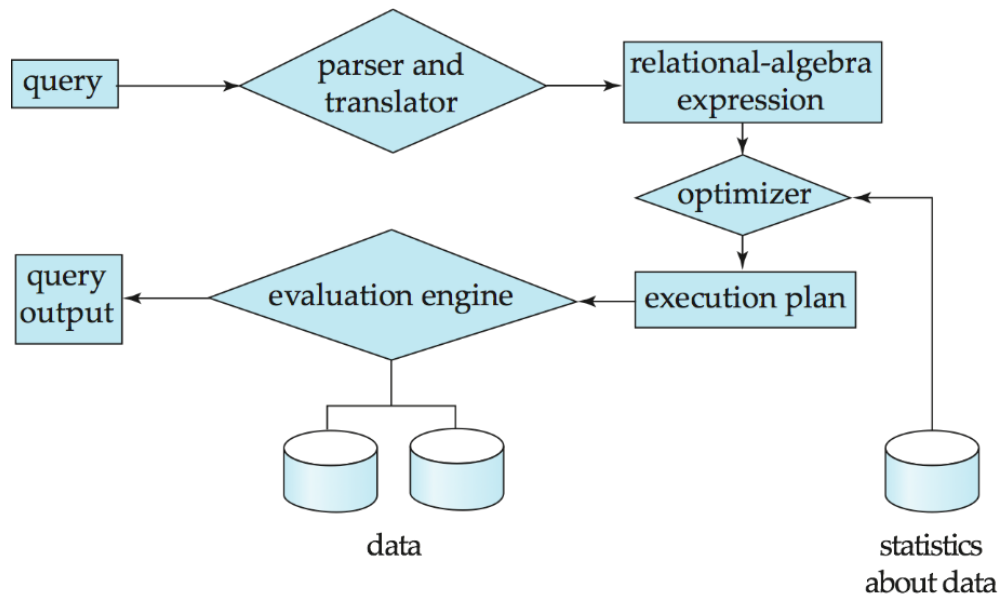
- **Storage manager**
  - minimize the need to move data between disk and main memory
- **Query processor**
  - translate updates and queries written in a nonprocedural language, at the **logical level**, into an efficient sequence of operations at the **physical level** such that helps the database system to simplify and facilitate access to data
- **Transaction manager**
  - ensures that the database remains in a consistent (correct) state despite system failures, and that concurrent transaction executions proceed without conflicting

# Storage Management

- **Storage manager** is a program module that provides the interface between the low-level data stored in the database and the application programs and queries submitted to the system.
- The storage manager is responsible for the following tasks:
  - Interaction with the file manager
    - The raw data are stored on the disk using the file system provided by the operating system. The storage manager translates the various DML statements into low-level file-system commands.
  - Efficient storing, retrieving and updating of data
- **Issues:**
  - Storage access
  - File organization
  - Indexing and hashing

# Query Processor Components

- **DDL interpreter**
  - **Parsing and translation**: interprets DDL statements and records the definitions in the data dictionary.
- **DML compiler**
  - Translates DML statements in a query language into an **evaluation plan** consisting of low-level instructions that the query evaluation engine understands.
  - **Query optimization**
- **Query evaluation engine**
  - Executes low-level instructions generated by the DML compiler



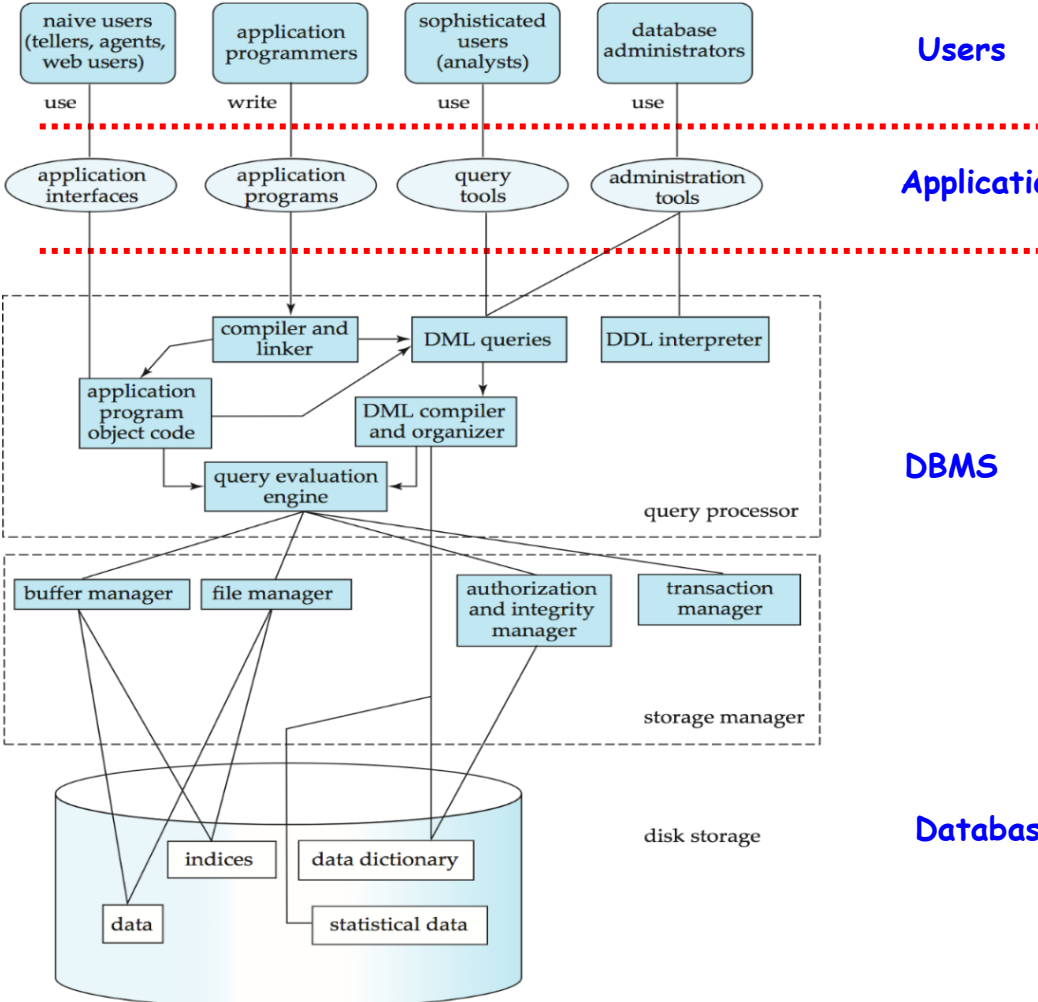
# Transaction Management

- **Transaction**
  - a collection of operations that perform a single logical function in a database application
  - **Atomicity/consistency/isolation/durability (ACID)**
- **Transaction manager**
  - Ensure that the database remains in a **consistent (correct) state** despite system failures (e.g., power failures and operating system crashes) and transaction failures.
- **Concurrency control manager**
  - Control the interaction among the concurrent transactions to ensure the consistency of the database.
- **Recovery manager**
  - Failure recovery

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# Database System Structure



Users

Applications/tools

DBMS

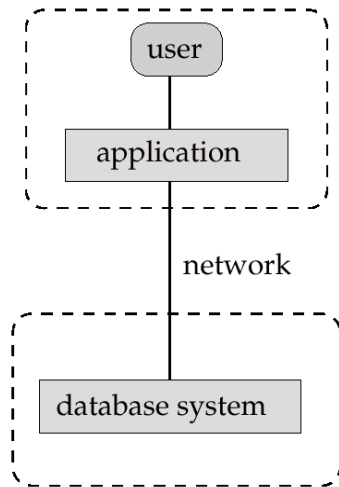
Database

# Database Architecture

- The architecture of a database systems is greatly influenced by the underlying computer system on which the database is running:
  - **Centralized**
  - **Client-server / Browser-server**
  - **Parallel (multi-processor)**
  - **Distributed**

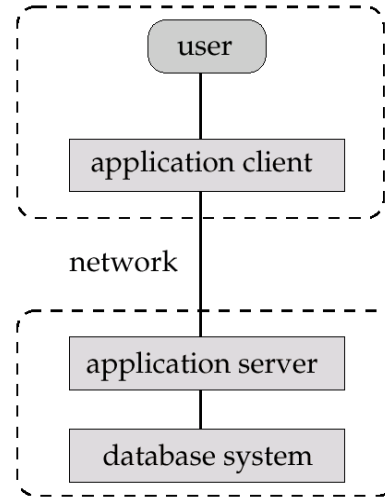


# Application Architectures



a. two-tier architecture

client



server

b. three-tier architecture

- **Two-tier architecture:** e.g., client programs using ODBC/JDBC to communicate with a database
- **Three-tier architecture:** e.g., web-based applications, and applications built using "middleware"

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# Database Users

- Users are differentiated by the way they interact with the system
  - **Naive users** (无经验用户)
    - Use application programs that have been developed previously
    - E.g., people accessing database over the web, bank tellers, various apps
  - **Application programmers** (应用程序员)
    - Interact with system through DML calls
  - **Sophisticated users** (熟练用户)
    - Form requests in a database query language
  - **Specialized users** (专业用户)
    - Write specialized database applications that do not fit into the traditional data processing framework
    - computer-aided design systems, knowledge base and expert systems, systems that store data with complex data types (e.g., graphics data and audio data), and environment-modeling systems


# People Working with DBMS

- **End users**
  - Query/update databases through application user interfaces (e.g., Amazon.com, 同心云, 本研一体化系统, etc.)
- **Database designers**
  - Design database "schema" to model the real world
- **Database application developers**
  - Build applications that interact with databases
- **Database administrators (a.k.a. DBA)**
  - Load, back up, and restore data
  - Fine-tune databases for better performance
- **DBMS implementors**
  - Develop the DBMS or specialized data management software
  - Implement new techniques for query processing and optimization inside DBMS

# Database Administrator (DBA)

- Coordinate all the activities of the database system, and have a good understanding of the enterprise's information resources and needs, as well as DBMS
- **DBA's duties**
  - Schema definition
  - Storage structure and access method definition
  - Schema and physical organization modification
  - Granting of authorization for data access
  - Routine maintenance
  - Specify integrity constraints
  - Act as liaison with users
  - Monitor performance, and respond to changes in requirements

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# History of Database Systems

- **1950s and early 1960s:**
  - Data processing using magnetic tapes for storage
    - Tapes provide only sequential access
  - Punched cards for input
- **Late 1960s and 1970s:**
  - Hard disks allow direct access to data
  - Network and hierarchical data models in widespread use
  - **Edgar F Codd defines the relational data model**
    - Won the ACM Turing Award for this work
    - IBM Research begins System R prototype
    - UC Berkeley begins Ingres prototype
  - High-performance (for the era) **transaction processing**
- **1980s:**
  - Relational prototypes evolve into commercial systems
    - **SQL becomes industrial standard**
  - Parallel and distributed database systems
  - Object-oriented database systems
- **1990s:**
  - Large decision support and data-mining applications
  - Large multi-terabyte data warehouses
  - Emergence of Web commerce
- **2000s**
  - **Big data** storage systems
    - Google BigTable, MapReduce, Yahoo PNuts, Amazon
    - "NoSQL" systems.
  - Big data analysis: beyond SQL
- **2010s**
  - Massive distributed database systems
  - Multi-core main-memory databases
  - Automated database administration
  - Streaming, mobile, trusted, uncertain data management
  - Cloud-native databases
- **2020s**
  - DB+AI

# Milestones in DBMS History (1)

- **Factor out data management** functionalities from applications and standardize these functionalities
  - CODASYL (Conference on Data Systems Language) standard (circa 1960's)
  - Developed **the first database management system IDS** (Integrated Data Store)
  - **Charles Bachman got a Turing award in 1973**



Charles Bachman  
(Dec. 11, 1924 - July 13, 2017)

Master of Upen

He received the [ACM Turing Award](#) in [1973](#) for "his outstanding contributions to database technology"



# Milestones in DBMS History (2)

- **The relational revolution (1970's)**
  - A simple data model: data is stored in **relations (tables)**
  - A declarative query language: **SQL**
  - Provided physical data independence
    - The single most important reason behind the success of DBMS today
  - **A Turing Award for E. F. Codd in 1981**



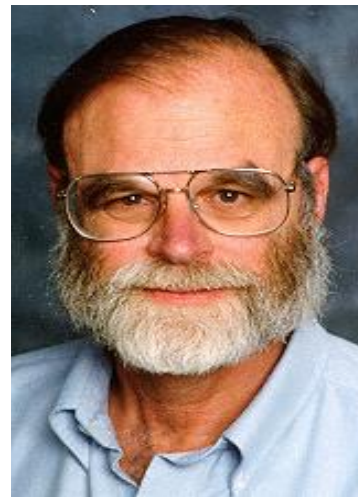
E. F. Codd  
(August 23rd, 1923 - April 18th, 2003)

Bachelor of Oxford, PhD of Michigan

E. F. Codd, [A Relational Model of Data for Large Shared Data Banks](#), Communications of ACM 13, No. 6, June 1970.

# Milestones in DBMS History (3)

- Transaction processing in 1980s
- Jim Gray got a Turing Award for this work in 1998
- Jim Gray was lost at sea on 28 Jan, 2007
- In 2008, Microsoft announced the opening of Microsoft Jim Gray Systems Lab in Madison, Wisconsin



Jim Gray (1944-2007)  
the first CS PhD of Berkeley

He received the [Turing Award](#) in [1998](#) "for seminal contributions to [database](#) and [transaction processing](#) research and technical leadership in system implementation."

# Back in 2009, I had a guess.....

## Who Will Be the Next Turing Award Winner in Database Field? (1)

- ❑ Some information about the three Turing Award winners in database field
  - Graduate from famous universities
    - Charles Bachman (Master of Upen)
    - E. F. Codd (Bachelor of Oxford, PhD of Univ. of Michigan )
    - Jim Gray (the first CS PhD of Berkeley)
  - All worked for IT industries for a long time
  - Active in academy and contributed a lot to database development

# Back in 2009, I had a guess.....

## Who Will Be the Next Turing Award Winner in Database Field? (2)

- ❑ My guess: Michael Stonebraker (1943-)
  - Bachelor (Princeton); Master/PhD (U. of Michigan)
  - Prof. (Berkeley); Adjunct Prof. (MIT)
  - His career covers, and helped create, the majority of the existing relational database market today. He is also the founder of [Ingres](#), [Illustra](#), [StreamBase Systems](#), [Vertica](#), [VoltDB](#), [SciDB](#) and was previously the [CTO](#) of [Informix](#)
  - He has received several awards, including the IEEE John von Neumann Medal and the first SIGMOD Edgar F. Codd Innovations Award. In 1994 he was inducted as a Fellow of ACM



# Milestones in DBMS History (4)

- **Michael Stonebraker (1943-)**

- His career covers, and helped create, the majority of the existing relational database market today. He is also the founder of Ingres (PostgreSQL的前身), Illustra, StreamBase Systems, Vertica, VoltDB, SciDB and was previously the CTO of Informix
- He has received several awards, including the **IEEE John von Neumann Medal** and **the first SIGMOD Edgar F. Codd Innovations Award**. He was inducted as a Fellow of ACM in 1994
- **2014 ACM Turing Award Winner** for **fundamental contributions to the concepts and practices** underlying modern database systems



Michael Stonebraker (1943-)

Bachelor (Princeton);  
Master/PhD (U. of Michigan)  
Prof. (Berkeley);  
Adjunct Prof. (MIT)

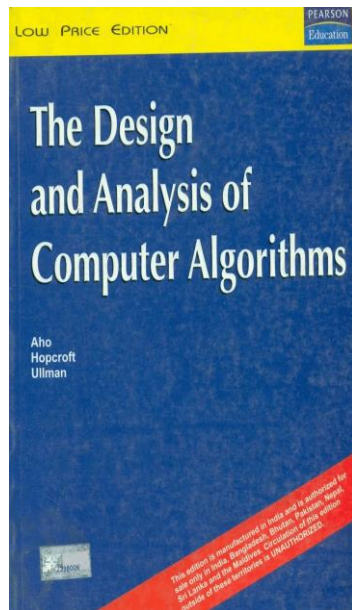
# Jeffrey Ullman



## AWARDS & RECOGNITION

### ACM Announces 2020 Turing Award Recipients

ACM has named **Alfred Aho**, Lawrence Gussman Professor Emeritus at Columbia University, and **Jeffrey Ullman**, Stanford W. Ascherman Professor Emeritus at Stanford University and CEO of Gradiance Corporation, recipients of the 2020 ACM A.M. Turing Award for fundamental algorithms and theory underlying programming language implementation, and for synthesizing these results and those of others in their highly influential books, which educated generations of computer scientists.



《计算机算法设计与分析》(1974)

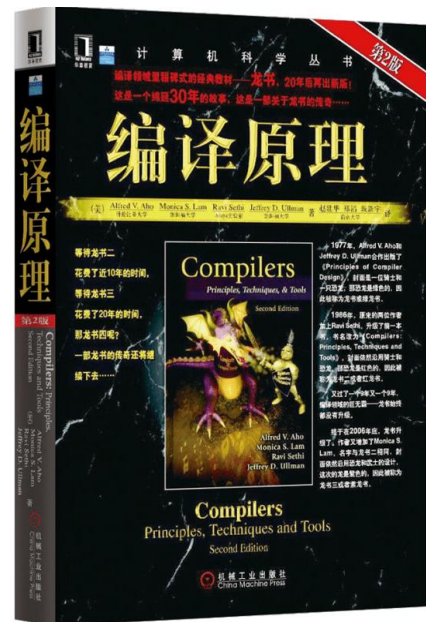
《The Design and Analysis of Computer Algorithms》



《编译程序设计原理》(1977)

《Principles of Compiler Design》(1977)

这本书最新版本《编译原理》(与Ravi Sethi和Monica Lam合著)于2007年出版,至今仍是有关编译器设计的标准教科书



## And, the next?

- The deep learning big guys
  - Geoffrey E. Hinton
  - Yoshua Bengio
  - Yann LeCun



# They Got the 2018 Award!!!



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Computing Machinery

*Advancing Computing as a Science & Profession*

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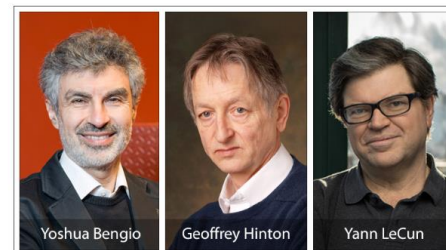
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[Home](#) > [Newsletters](#) > [ACM Bulletins](#) > [2018 Turing Award Recipients](#)

## ACM Announces 2018 Turing Award Recipients

March 27, 2019

ACM has named Yoshua Bengio, Geoffrey Hinton, and Yann LeCun recipients of the [2018 ACM A.M. Turing Award](#) for conceptual and engineering breakthroughs that have made deep neural networks a critical component of computing.



Yoshua Bengio

Geoffrey Hinton

Yann LeCun



# A Slide in My Lecture 1 of Database in 2016

Then, who will be the next lucky guy?



# A Slide in My Lecture 1 of Database in 2016

Then, who will be the next database lucky guy?





















- ❑ It is too early to say which database guy will get the award
- ❑ But, if I'm a member of Turing Award Committee, I would like to nominate Dr. Rakesh Agrawal for his contribution to the techniques and applications of data mining



School of C.S. Fudan Univ.

# Alan Turing Award Committee

## A. M. Turing Award

Title	Name	Email	Digital Library
Chair	Michael Kearns		
Member	Monika Henzinger		
Member	Surajit Chaudhuri		
Member	Pat Hanrahan		
Member	Norm Jouppi		
Member	Stuart Russell		
Member	Margo Seltzer		
Member	Luca Trevisan		
Member	Manuela Veloso		
Member	Jeannette Wing		

# Major DBMS Today

- **Major commercial DBMS products**
  - Oracle
  - IBM DB2 (from System R, System R\*, Starburst)
  - Microsoft SQL Server
  - Sybase
  - Informix (acquired by IBM), ...
- **Open source DBMS**
  - PostgreSQL (from UC Berkeley's Ingres, Postgres)
  - MySQL
- **Others**
  - NoSQL (Not only SQL, for big data): HBase, MongoDB, Neo4J, Redis, Cassandra
  - NewSQL: **OceanBase**, **openGauss**, etc.

# DB-Engine Ranking

422 systems in ranking, September 2023

Rank			DBMS	Database Model	Score		
Sep 2023	Aug 2023	Sep 2022			Sep 2023	Aug 2023	Sep 2022
1.	1.	1.	Oracle +	Relational, Multi-model	1240.88	-1.22	+2.62
2.	2.	2.	MySQL +	Relational, Multi-model	1111.49	-18.97	-100.98
3.	3.	3.	Microsoft SQL Server +	Relational, Multi-model	902.22	-18.60	-24.08
4.	4.	4.	PostgreSQL +	Relational, Multi-model	620.75	+0.37	+0.29
5.	5.	5.	MongoDB +	Document, Multi-model	439.42	+4.93	-50.21
6.	6.	6.	Redis +	Key-value, Multi-model	163.68	+0.72	-17.79
7.	7.	7.	Elasticsearch	Search engine, Multi-model	138.98	-0.94	-12.46
8.	8.	8.	IBM Db2	Relational, Multi-model	136.72	-2.52	-14.67
9.	10.	10.	SQLite +	Relational	129.20	-0.72	-9.62
10.	9.	9.	Microsoft Access	Relational	128.56	-1.78	-11.47
11.	11.	13.	Snowflake +	Relational	120.89	+0.27	+17.39
12.	12.	11.	Cassandra +	Wide column, Multi-model	110.06	+2.67	-9.06
13.	13.	12.	MariaDB +	Relational, Multi-model	100.45	+1.80	-9.70
14.	14.	14.	Splunk	Search engine	91.40	+2.42	-2.65
15.	16.	16.	Microsoft Azure SQL Database	Relational, Multi-model	82.73	+3.22	-1.69
16.	15.	15.	Amazon DynamoDB +	Multi-model	80.91	-2.64	-6.51
17.	18.	20.	Databricks	Multi-model	75.18	+3.84	+19.56
18.	17.	17.	Hive	Relational	71.83	-1.52	-6.60
19.	19.	18.	Teradata	Relational, Multi-model	60.33	-0.98	-6.25
20.	20.	24.	Google BigQuery +	Relational	56.46	+2.56	+6.34

## Oracle: Multi-model

**Relational DBMS,**  
Document store,  
Graph DBMS,  
RDF store,  
Spatial DBMS

## Redis: Multi-model

**Key-value store,**  
Document store,  
Graph DBMS,  
Spatial DBMS,  
Search engine,  
Time Series DBMS,  
Vector DBMS

# 产业图谱 - 中国数据库产品图谱家族



非关系型

Analytic



关系型



OLAP

NoSQL



OpenMLDB



云数据库



OLTP



分布式



# 蚂蚁金服OceanBase简介

- OceanBase由蚂蚁金服完全自主研发的**金融级分布式关系数据库**，创于2010年，具有数据强一致、高可用、高性能、在线扩展、高度兼容SQL标准和主流关系数据库、低成本特点。
- OceanBase已经在建设银行、南京银行、西安银行、人保健康险、常熟农商行、苏州银行、广东农信、网商银行等多家商业银行和保险机构上线。
- 2020年5月，OceanBase以**7.07亿 (707,351,007) tpmC**（即每分钟内系统处理的新订单个数，transactions per minute, TPC-C）的在线事务处理性能，打破了OceanBase自己在2019年10月创造的**6088万 (60,880,800) tpmC**的TPC-C世界纪录(Oracle 为30,249,688)。
- 2020年6月8日，蚂蚁集团宣布，将自研数据库产品OceanBase独立进行公司化运作，成立由蚂蚁100%控股的数据库公司**北京奥星贝斯科技**，并由蚂蚁集团CEO胡晓明亲自担任董事长。
- OceanBase是一个**支持海量数据的高性能分布式数据库系统**，实现了数千亿条记录、数百TB数据上跨行跨表事务，由淘宝核心系统研发、运维、DBA、广告、应用研发等部门共同完成。在设计和实现OceanBase的时候暂时摒弃不紧急的DBMS的功能，例如临时表、视图view等，研发团队把有限的资源集中到关键点上，**当前 OceanBase主要解决数据更新一致性、高性能的跨表读事务、范围查询、join、数据全量及增量dump、批量数据导入等**

# 华为openGauss简介

- **GaussDB** 数据库是2019年 5 月 15 日华为在北京面向全球发布的，被称为**全球首个人工智能原生 (AI-Native) 数据库**。
- 根据华为的介绍，GaussDB 具有两大革命性突破：
  - **首次将 AI 技术融入分布式数据库的全生命周期**，实现自运维、自管理、自调优、故障自诊断和自愈。在交易、分析和混合负载场景下，基于最优化理论，首创**基于深度强化学习的自调优算法**，调优性能比业界提升 85%
  - 通过**异构计算创新框架**充分发挥多种算力优势，在权威标准测试集 **TPC-DS** 上，性能比业界提升 48%
- 2019年9月19日在华为全联接大会上，华为宣布将**开源**其数据库产品，开源后命名为**openGauss**，2020年6月30日openGauss数据库源代码正式开放。
- openGauss是一款**开源关系型数据库管理系统**，采用木兰宽松许可证v2发行。openGauss**内核源自PostgreSQL**，深度融合华为在数据库领域多年的经验，结合企业级场景需求，持续构建竞争力特性。同时openGauss也是一个开源、免费的数据库平台，鼓励社区贡献、合作。



# Outline

- Data, information, knowledge and beyond
- Database system
- Data view
- DB languages
- DB design
- DB engine
- Database architecture
- DB user and administrator
- History of DB
- ☞ **Future directions**

# A Great Tradition

- Over the last thirty years, small groups of database researchers, practitioners and opinionated professionals have periodically gathered to assess the state of the field and propose directions for future research
  - 1988, 1990, 1995, 1998, 2003, 2008, 2013, 2018, 2023
- A final report will come out after each meeting, which aims to serve various functions: to foster debate within the database research community, to explain research directions to external organizations, and to help focus community efforts on timely challenges

# The Database Meetings

- ❑ 1988 The Laguna Beach Participants
- ❑ 1990 The Palo Alto Report (NSF)
- ❑ 1995 Database research: achievements and opportunities into 21st century (NSF)
- ❑ 1998 The Asilomar Report on Database Research
- ❑ 2003 The Lowell Database Research Self-Assessment
- ❑ 2008 The Claremont Report on Database Research
- ❑ 2013 The Beckman Report on Database Research
- ❑ 2018 The Seattle Report on Database Research
- ❑ 2023 The Boston Report on Database Research

# 2008 Claremont Meeting

- Eric A. Brewer, **Michael Stonebraker**, Joseph M. Hellerstein, Michael J. Franklin (Berkeley)
- **Rakesh Agrawal** (Yahoo!)
- Philip A. Bernstein, Surajit Chaudhuri (Microsoft)
- Michael J. Carey (UC Irvine); AnHai Doan (UWM)
- Hector Garcia - Molina (Stanford)
- Johannes Gehrke (Cornell), Le Gruenwald (OU)
- Laura M. Haas (IBM)
- Raghu Ramakrishnan (Google); Alon Y. Halevy (Washington U./Google!)
- Samuel Madden (MIT); Hank F. Korth (Lehigh U.); Alexander S. Szalay (HJU)
- Roger Magoulas, Tim O'Reilly (O'Reilly Media )
- Donald Kossmann (ETH); Anastasia Ailamaki (EPFL)
- Gerhard Weikum (MPI for CS); Yannis E. Ioannidis (UOA); Daniela Florescu (INRIA)
- **Beng Chin Ooi (NUS)**, Sunita Sarawagi (IIT Bombay)



# 2008 Claremont Meeting: Challenges

- **Big Data**
  - the number of communities working with large volumes of data has grown considerably, to include not only traditional enterprise applications and Web search, but also "e-science" efforts (in astronomy, biology, earth science, etc.), digital entertainment, natural language processing, social network analysis, and more
- **Data analysis as a profit center (Data center / Cloud Computing)**
- **Ubiquity of structured and unstructured data**
- **Expanded developer demands**
  - Programmer adoption of relational DBMSs and query languages has grown significantly in recent years
- **Architectural shifts in computing**
  - At the macro scale, the rise of "cloud" computing services suggests fundamental changes in software architecture
  - At a micro scale, computer architectures have shifted the focus of Moore's Law from increasing clock speed per chip to increasing **the number of processor cores and threads per chip**
  - In storage technologies, major changes are underway in the memory hierarchy, due to the availability of **more and larger on-chip caches, large inexpensive RAM, and flash memory**
  - **Power consumption** has become an increasingly important aspect of the price/performance metric of large systems

# 2013 Beckman Meeting



# 2013 Beckman Meeting: Challenges

- Scalable big/fast data infrastructures
  - How dealing data volume ?
- Coping with diversity in the data management landscape
  - How dealing data variety ?
- End-to-end processing and understanding of data
  - How dealing data velocity?
- **Cloud services**
  - How deploying Big Data applications in the cloud ?
- The roles of people in the data life cycle
  - How managing the involvement of people in these applications ?

# 2018 Seattle Meeting: Participants

- Daniel Abadi, Anastasia Ailamaki, David Andersen
- Peter Bailis, Magdalena Balazinska, Phil Bernstein
- Peter Boncz, Surajit Chaudhuri, **Alvin Cheung**
- Anhai Doan, **Luna Dong**, Mike Franklin, Juliana Freire
- Alon Halevy, Joe Hellerstein, Stratos Idreos
- Donald Kossman, Tim Kraska, Sailesh Krishnamurthy,
- Volker Markl, Sergey Melnik, Tova Milo, C. Mohan,
- Thomas Neumann, **Beng Chin Ooi**, Fatma Ozcan
- Jignesh Patel, Andy Pavlo, Raluca Popa
- Raghu Ramakrishnan, Christopher Re
- **Mike Stonebraker**, and Dan Suciu



# 2018 Seattle: Challenges

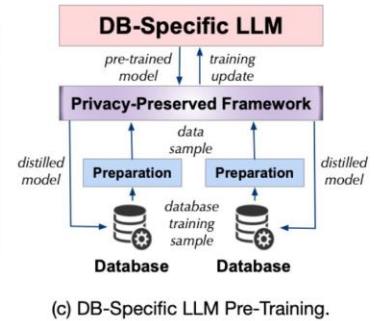
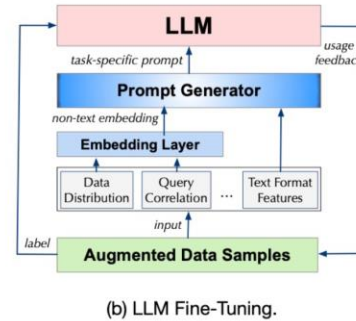
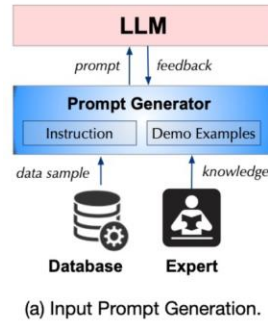
- Data science
- Data governance
- Cloud services
- Database engines
  - Data lakes and modern data warehousing applications:
  - Leveraging machine learning
- Community

# 2023 Boston Meeting



# 2023 Boston Meeting: Challenges

- Cloud-native
  - Data Federation
  - Data Marketing, Data Sharing
  - Data ecosystem
  - Data compiler
- AI/LLM
  - Control, Compute, Storage
  - Retrieval Augmented Generation
  - LLM Agent
  - NL2SQL
  - LLM as Chips/OS
- Future of Database Engines
- Applications, industry, and DB community



# Topics of DB Meetings

	1998	1990	1995	1998	2003	2008	2013	2018	2023
More data types: Image, spatial, time, genetics	√	√	√	√		√			
Information retrieval	√			√	√				
Data mining		√	√	√	√				
Extendible DBMSs, object-oriented DBMSs	√		√	√					
Exploit hardware advances	√			√	√			√	
Parallelism, scale-up, scale-out	√	√			√				
High availability, replication	√		√						
Workflow models, long transactions, workflow engines	√	√	√	√					
Heterogeneous DBMSs, semantic consistency, data fusion	√	√	√	√	√				
Uncertain and probabilistic data, data quality		√	√	√	√				
Privacy and Trustworthy	√				√				
One-Hundred-Year Storage	√				√				
Real-time DBs, streams, sensor networks, sensor	√				√				
Schema-less DBs, unify unstructured and structured data	√				√	√			
User interfaces for DBs	√		√		√	√			
Web, Multimedia, Mobile App			√	√	√	√			

# Topics of DB Meetings

	1998	1990	1995	1998	2003	2008	2013	2018	2023
Mobile Applications and Virtual Worlds					√	√			
Federate Database Systems, Declarative Programming						√			
Human-in-the-loop data management							√		
Data science pipeline, Data system landscape							√		
Big data						√	√		
DB engines: AQP								√	
DB engines: ML								√	√
DB engines: benchmark								√	√
DB engines: heterogeneous computation								√	√
DB engines: data lakes								√	
Cloud DB: disaggregation, multi-tenancy							√	√	√
Cloud DB: hybrid cloud							√	√	
Cloud DB: edge and cloud							√	√	
Data Science: data integration and wrangling								√	√
Data Science: data provenance, governance, sharing, ethical								√	√
Community: ecosystem, impact, education							√	√	√

# Summary

- Database, database system, DBMS and its benefits
- Drawbacks of file system to store data
- Levels of abstraction: physical/logical/view levels
- Physical/logical independence
- Entity-Relational(ER) model/Relational model
- DDL/DML (SQL)
- Database design: logical/physical design
- Database engine: storage/query/transaction manager
- Components of storage management
- Components of query processor
- Transaction manager: Recovery/concurrency-control manager
- Architecture of database system
- Users of database
- Duties of database administrator (DBA)
- Differences among database, data mining and information retrieval

# Review Terms

- Database management system (DBMS)
- Data system applications
- File processing systems
- Data inconsistency
- Consistency constraints
- Data abstraction
- Instance
- Schema
  - Physical schema
  - Logical schema
- Physical data independence
- Data models
  - Entity-relationship model
  - Relational data model
  - Object-based data model
  - Semi-structured data model
- Database languages
  - Data definition language (DDL)
  - Data manipulation language (DML)
  - Query language
- Metadata
- Application program
- Normalization
- Data dictionary
- Storage manager
- Query processor
- Transactions
  - Atomicity
  - Failure recovery
  - Concurrency control
- Two- and three-tier database architectures
- Data mining
- Database administrator (DBA)

# Some useful terms

- **Byte**
- **Kilobyte** -  $2^{10}$  bytes (i.e. 1024 bytes)
- **Megabyte** -  $2^{20}$  bytes (i.e. 1024 kilobytes)
- **Gigabyte** -  $2^{30}$  bytes (i.e. 1024 megabytes)
- **Terabyte** -  $2^{40}$  bytes (i.e. 1024 gigabytes)
- **Petabyte** -  $2^{50}$  bytes (i.e. 1024 terabytes)
- **Exabyte** -  $2^{60}$  bytes (i.e. 1024 petabytes)
- **Zettabyte** -  $2^{70}$  bytes (i.e. 1024 exabytes)
- **Yottabyte** -  $2^{80}$  bytes (i.e. 1024 zettabytes)





# 先进数据与机器智能系统实验室

Advanced Data and Machine Intelligence Systems (ADMIS) Lab

## (周水庚实验室)

周水庚

上海市智能信息处理重点实验室

复旦大学计算机学院

Email: [sgzhou@fudan.edu.cn](mailto:sgzhou@fudan.edu.cn)

URL: <http://admis.fudan.edu.cn/sgzhou>



# 主页

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## Shuigeng Zhou (周水庚)

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Shuigeng Zhou is a full professor (since 2003) at the [School of Computer Science, Fudan University](#), the director (since Sept. 2018, vice-director from 2004 to Aug. 2018) of [Shanghai Key Lab of Intelligent Information Processing](#), Fudan University. He also leads the research group of [Advanced Data Mining and Intelligent Systems \(ADMIS\)](#). He was the Vice Chairman (in charge of research affairs) of the Department of Computer Science and Engineering, Fudan University, from January 2005 to May 2008. The CSE Department was merged into the School of Computer Science, Fudan University in May 2008.

Shuigeng Zhou received his Bachelor Degree of Engineering from [Huazhong University of Science and Technology \(HUST\)](#) in July 1988, his Master Degree of Engineering from [University of Electronic Science and Technology of China \(UESTC\)](#) in March 1991, and his PhD of Computer Science from [Fudan University](#) in July 2000. He served in [Shanghai Academy of Spaceflight Technology](#) from April 1991 to August 1997, as an engineer and a senior engineer (since August 1995) respectively. Before

# Google Scholar Profile



Shuigeng Zhou

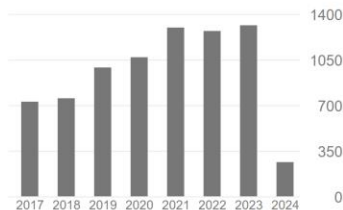
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# 先进数据与机器智能系统实验室

Advanced Data and Machine Intelligence Systems (ADMIS) Lab



- 人员组成 (46+)
  - 1位教授、2位副教授
  - 1位博士后、14博士生和28硕士生
  - 一些高年级本科生
- 主要研究领域
  - 人工智能、大数据管理与分析、网络与博弈、与生物和金融等的交叉研究
- 学术成果
  - 论文：国际学术论文400多篇，其中：国际期刊论文200多篇，国际顶级会议/期刊论文100多篇；
  - 专利：申请/授权发明专利62项目，授权23项
  - 获奖：获得省部级（教育部）科研奖励二等奖7项

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中华人民共和国工业和信息化部  
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HIKVISION



之江实验室



ZHEJIANG LAB

# 研究领域：人工智能



## ■ 深度学习及其应用

- 零（小）样本学习/目标检测、图像文本识别、视频分析、异常检测、声纹识别等
- NeurIPS'21/22, ICCV'17/19/23, CVPR'18/19/21, AAAI'21/20/19, IJCAI'22, ACM-MM'19/21/22/23, SIGIR'23

## ■ 人工智能安全与隐私保护

- 隐私保护的人脸识别、联邦学习
- CVPR'24, ICCV'23, ACM MM'22

## ■ 机器学习

- **因果推断** (IEEE TCYB 2020/2022, ACM TIST 2019, AAAI'17/18/19/21/22/23)
- 稀疏表示 (AAAI'14/15/16, ECAI'16)

## ■ 数据挖掘

- 图数据分类 (KDD'16)
- 流数据挖掘 (ICDE'08/09)
- 金融数据挖掘 (IJCAI'13/15, IEEE TKDE 2016, ACM TIST 2018)
- 异常检测 (KDD'06, AAAI'19)



# 研究领域：大数据管理与分析



- **大规模图数据查询处理**
  - SIGMOD'21/20/19/18/13/11, VLDB'17, ICDE'07/12/15/16, VLDBJ 2014/2020
- **隐私保护**
  - ICDE'14, SIGMOD'13, EDBT'12, IEEE TKDE 2009
- **路网查询处理**
  - SIGMOD'13/15, VLDB'12, IEEE TKDE 2017, IEEE TSC 2018
- **分布式查询与索引**
  - IEEE TKDE 2010/2009, IEEE TPDS 2011/2008
- **基于外存储的算法**
  - Algorithmica 2018, ICDT'15, VLDBJ 2014, SPAA'14, SODA'13

# 研究领域： 生物信息学与计算生物学



- 基因组
  - Nat. Comm. 2014/2019, Bioinformatics 2015, ACM/IEEE TCBB 2015 etc.
- 宏基因组 (Metagenomics)
  - ACM/IEEE TCBB 2014 etc.
- 表观遗传 (Epigenetics)
  - NAR 2016, BIB 2014 etc.
- 蛋白质组学 (蛋白质结构与功能预测)
  - NAR 2014, BIB 2014, RECOMB'13, Bioinformatics 2009/2023 etc.
- 转录组学 (miRNA聚类、分类及其靶基因预测)
  - ACM/IEEE TCBB 2015, Bioinformatics 2009 etc.
- 单细胞测序数据聚类分析
  - ACM/IEEE TCBB 2022, BIB 2022, JBCB 2020 etc.
- 基于人工智能的药物设计与发现
  - ACM/IEEE TCBB 2016, ISMB'15, Bioinformatics 2015/2021/2022 etc.

# 研究领域：金融信息处理



- 投资组合优化 (Portfolio)
  - IJCAI 2013/2015, IEEE TKDE 2016, ACM TIST 2018
- 市场预测
  - DASFAA 2015
- 最优交易
  - DASFAA 2020
- 金融欺诈检测
  - Neurocomputing, 2012



# 近年学生获得多个AI大赛奖

- 2023年海军“金海豚”算法挑战赛**两项冠军**
- 2021 CVPR压缩视频质量增强挑战赛 **冠军**
- 2018年全球AI挑战赛零样本学习 (ZSL) **冠军**
- 2018年未来高校AI挑战赛声纹认证组**冠军**
- 2017年ICDAR CoCo-Text**第一名**
- 2019年“默克杯”逆合成反应预测大赛**三等奖**
  
- 近年来，实验室研究生在人工智能相关的重要国际学术会议（包括 **NeurIPS, AAI, IJCAI, ICCV, CVPR, SIGKDD, SIGIR, ACM-MM**等）和期刊（包括**IEEE TKDE/TCYB, ACM TIST**等）发表/录用论文**40多篇**

# 欢迎同学们加盟并申报以下计划



- 荇政学者
- 曦源学者
- 望道学者
- .....

End of Lecture 1