Faculty of Computer Science and Engineering
Ho Chi Minh City University of Technology

Chapter 1:
An Overview of Database Systems

Database Systems (CO2013)

Computer Science Program

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Main references

Text:

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Chapter 1: An overview of database systems

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1.1. Concepts

- Data/ Information/ Knowledge/ Metadata
  - Data
  - Information
  - Knowledge
  - Metadata

  → Relative

Data

- information, especially facts or numbers, collected for examination and consideration and used to help decision-making, or information in an electronic form that can be stored and processed by a computer
  - Cambridge Advanced Learner's Dictionary
- an elementary description of things, events, activities, and transactions that are recorded, classified, and stored but not organized to convey any specific meaning
  - R. K. Rainer, C. G. Cegielski, "Introduction to Information Systems", 3rd Edition, John Wiley & Sons, Inc, pp. 10, 2004.

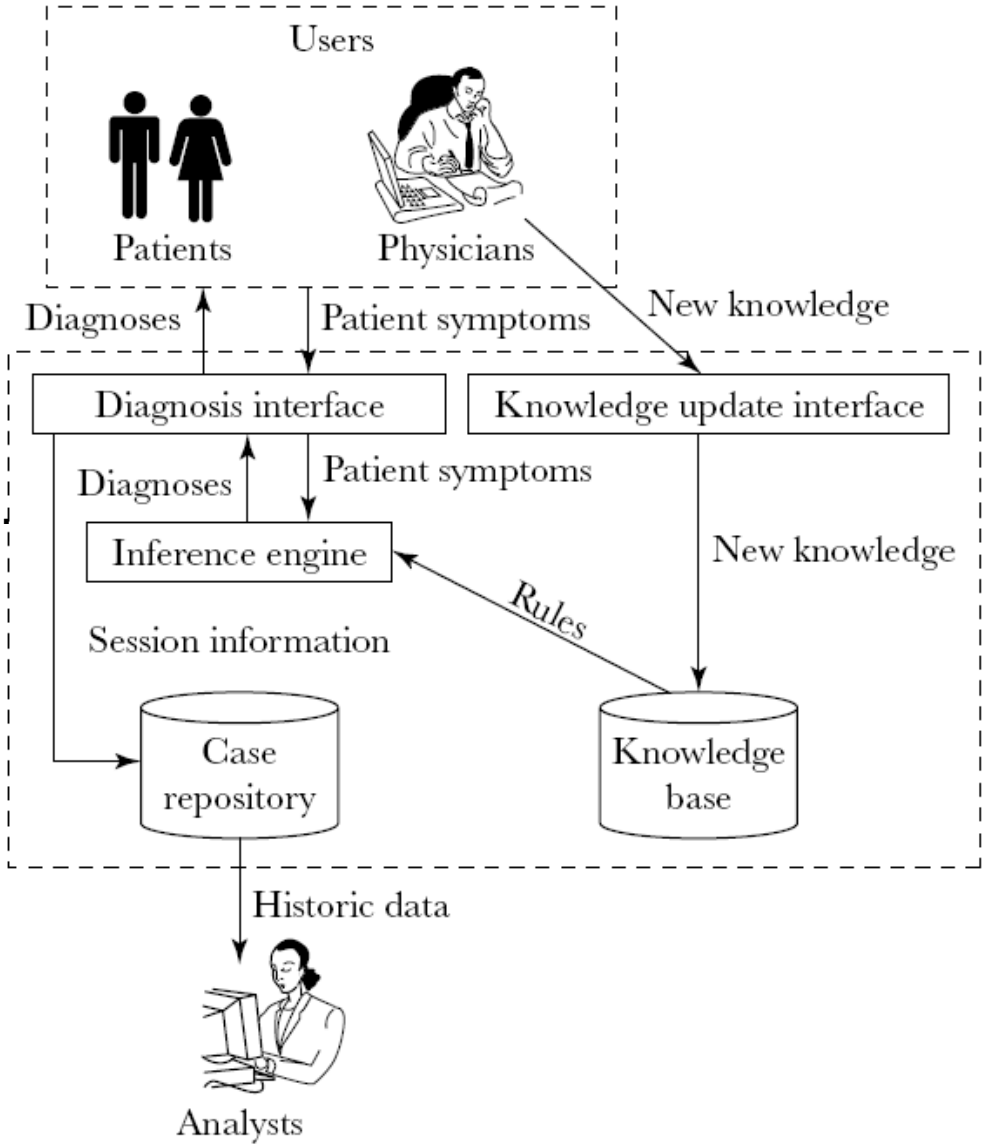
Data

Factual data and clinical evidence provided by a clinician or patient

→Bệnh nhân A: tên, địa chỉ, thân

nhiệt, hình ảnh về bệnh nhân, …

→ Bác sĩ B: giờ khám, tên thuốc, …



Kiến trúc của hệ hỗ trợ chẩn đoán dựa trên Web (architecture of a Web-based diagnosis support system)

Information

- facts about a situation, person, event, etc
  - Cambridge Advanced Learner's Dictionary
- data that have been organized so that they have meaning and value to the recipient

→ the recipient interprets the meaning and draws conclusions and implications from the information

  - R. K. Rainer, C. G. Cegielski, "Introduction to Information Systems", 3rd Edition, John Wiley & Sons, Inc, pp. 10, 2004.

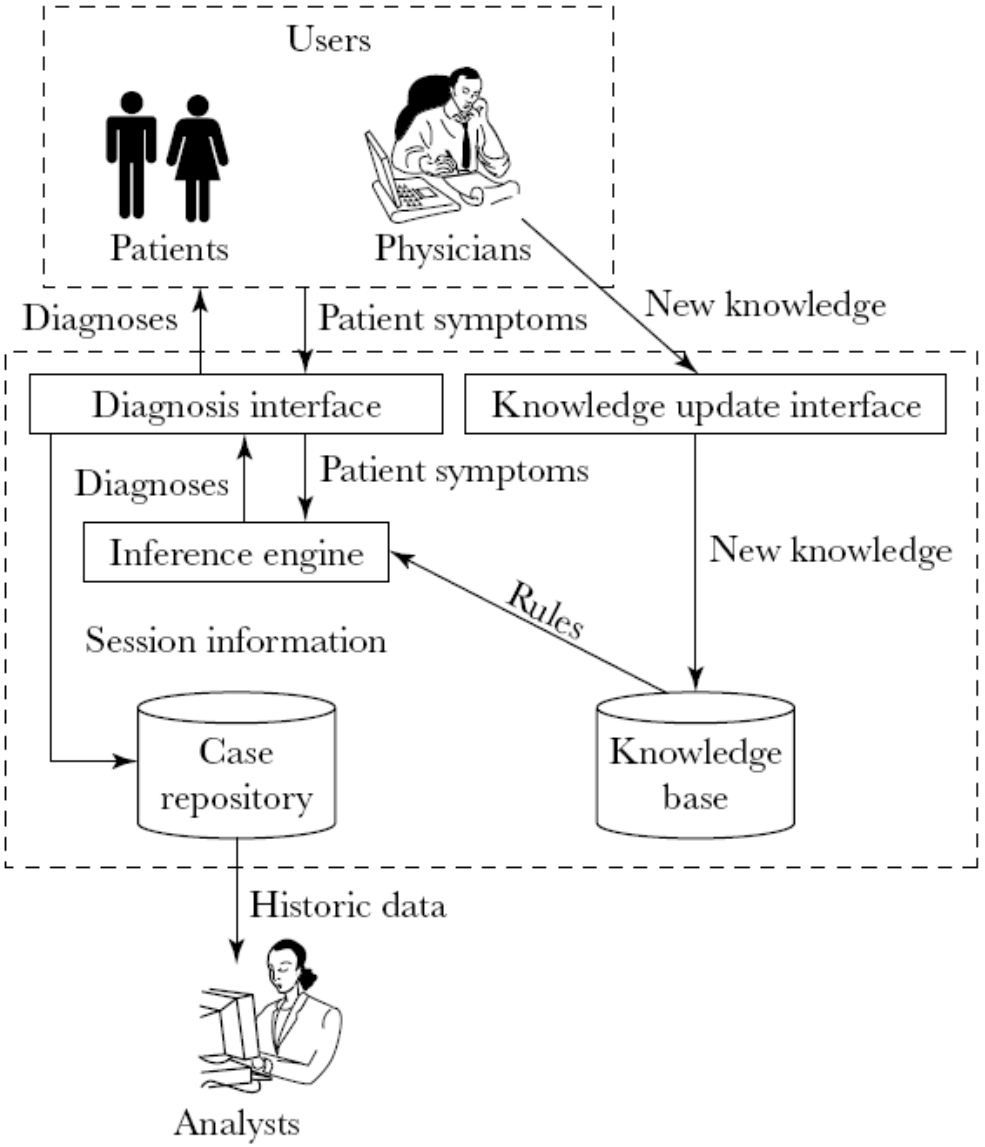
Information

Bệnh nhân A có thân nhiệt 37.5°.

Bác sĩ B chuyên chẩn đoán bệnh về tim mạch.

Mỗi tuần, trung bình 100 bệnh nhân tương tác với hệ thống.

…



Kiến trúc của hệ hỗ trợ chẩn đoán dựa trên Web (architecture of a Web-based diagnosis support system)

Knowledge

- Awareness; understanding of or information about a subject which has been obtained by experience or study, and which is either in a person's mind or possessed by people generally
  - Cambridge Advanced Learner's Dictionary
- data/information that have been organized and processed to convey understanding, experience, accumulated learning, and expertise as they apply to a current business problem
  - R. K. Rainer, C. G. Cegielski, "Introduction to Information Systems", 3rd Edition, John Wiley & Sons, Inc, pp. 10, 2004.

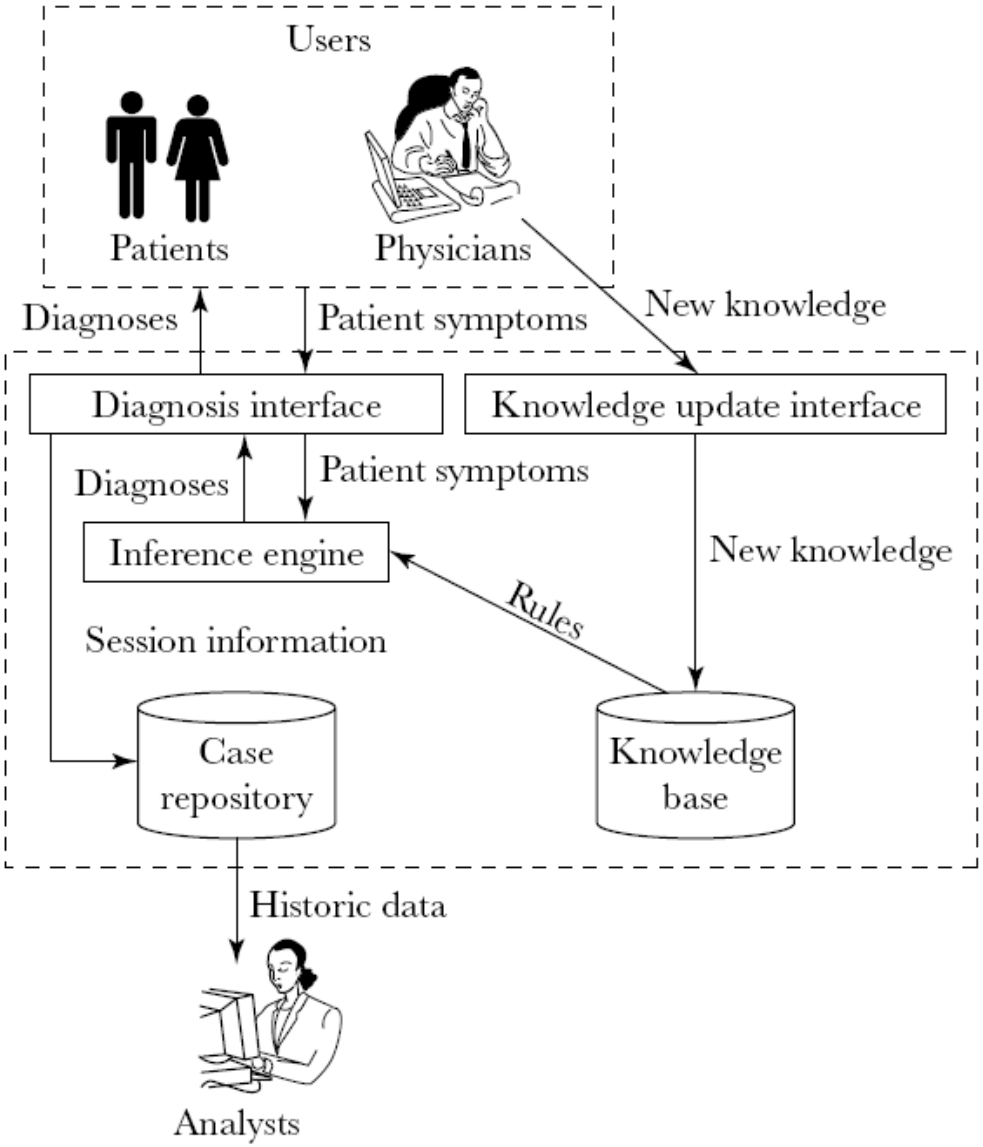
Knowledge

Nếu bệnh nhân có thân nhiệt cao trong vòng 3 ngày, có dấu hiệu mệt mỏi thì bệnh nhân đang có bệnh cúm.

Cho bệnh cúm nhẹ, bệnh nhân cần dùng thuốc …

Nếu thuốc được dùng trong vòng 5 ngày nhưng thân nhiệt không giảm thì bệnh nhân cần nhập viện thực hiện các xét nghiệm về máu, …

…



Kiến trúc của hệ hỗ trợ chẩn đoán dựa trên Web (architecture of a Web-based diagnosis support system)

Metadata

- Data about data
- Ví dụ: thông tin mô tả kỹ thuật của 1 word document: title, subject, author, manager, company, …
  - Data: content của word document
  - Metadata: data values của title, subject, author, manager, company, …

Database

- A collection of related data with an implicit meaning
- Implicit properties
  - A database represents some aspect of the real world, called the miniworld or the universe of discourse (UoD).
    - Changes to the miniworld are reflected in the database.
  - A database is a logically coherent collection of data with some inherent meaning.
    - A random assortment of data cannot correctly be referred to as a database.
  - A database is designed, built, and populated with data for a specific purpose.
    - It has an intended group of users and some preconceived applications in which these users are interested.
  - A database can be of any size and of varying complexity.

Database

Part of the Company database

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

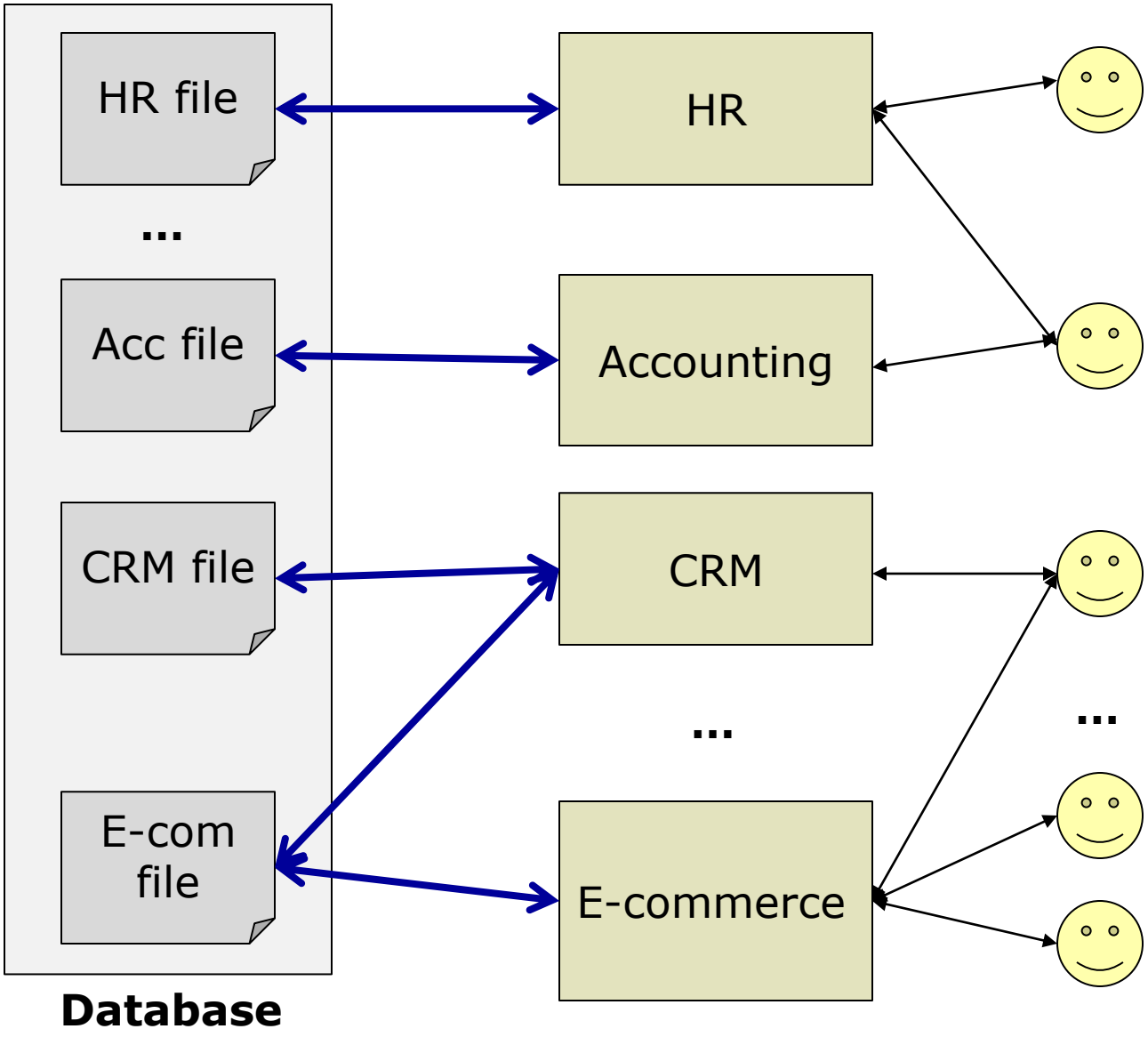
WORKS_ON

Essn	Pno	Hours
123456789	1	32.5
123456789	2	7.5
666884444	3	40.0
453453453	1	20.0
453453453	2	20.0
333445555	2	10.0

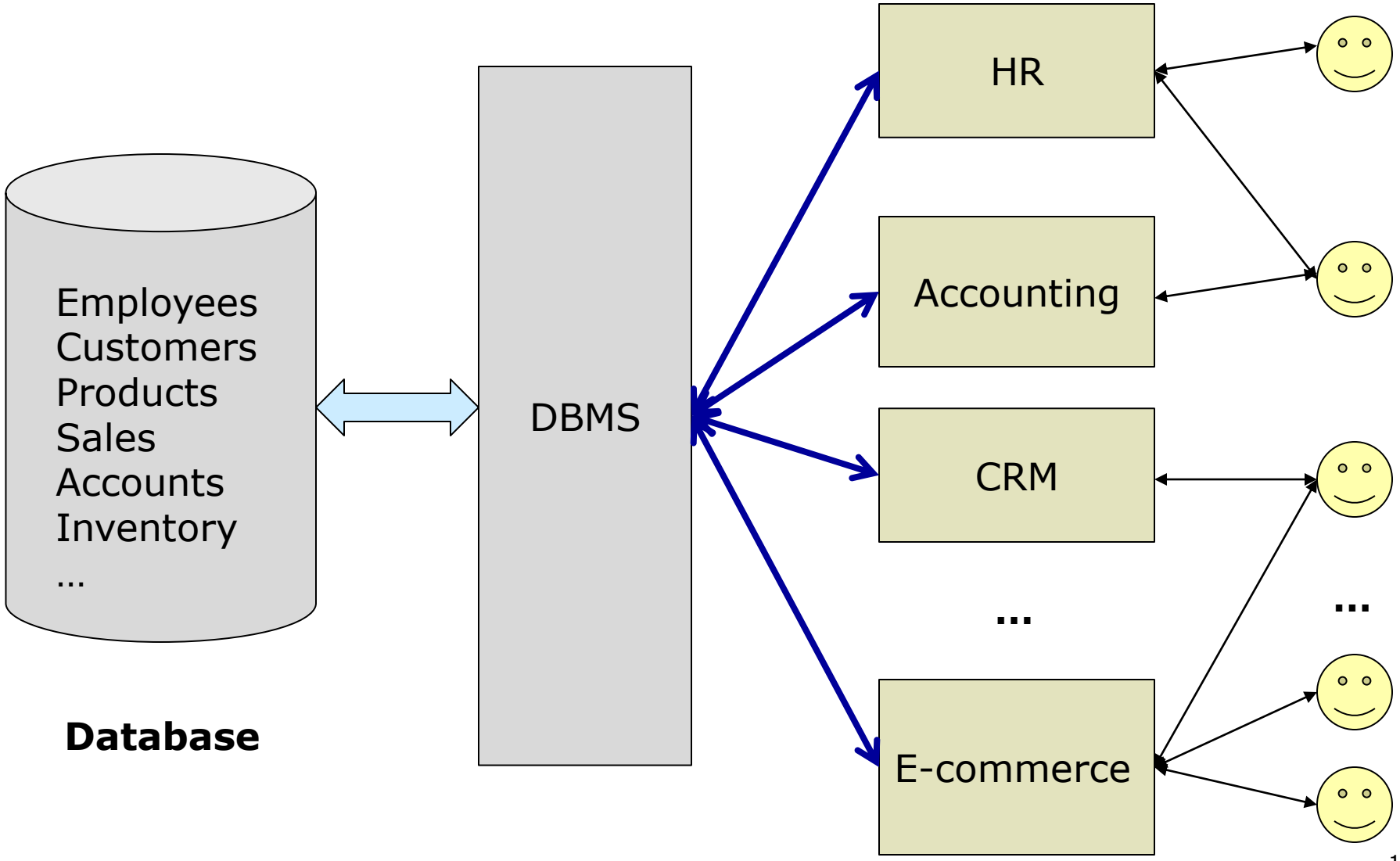
PROJECT

Pname	Pnumber	Plocation	Dnum
ProductX	1	Bellaire	5
ProductY	2	Sugarland	5
ProductZ	3	Houston	5
Computerization	10	Stafford	4
Reorganization	20	Houston	1
Newbenefits	30	Stafford	4

1.2. File processing systems



1.3. The database approach



File systems vs. Database systems

- File
  - Specifically define and implement the data files for *each user*'s needs
  - *Uncontrolled* data redundancy
  - *No* program-data independence
  - *Hard* maintenance
  - No overhead cost of a DBMS software
  - …
- Database
  - Define and implement the repository for various users' needs
  - Controlled data redundancy
  - Program-data independence
  - Easy maintenance
  - *Overhead cost* of a DBMS software
  - …

1.4. Data models

- Informally, a data model is a *type of data abstraction* that is used to provide this *conceptual representation*.
- The data model uses *logical concepts*, such as objects, their properties, and their interrelationships, that may be easier *for most users to understand* than computer storage concepts.
- The data model *hides storage and implementation details* that are not of interest to most database users.

Data model

E. F. Codd. Data models in database management, ACM, 1980.

- A combination of three following components
  - (1). A collection of *data structure types* (the building blocks of any database that conforms to the model);
  - (2). A collection of *operators or inferencing rules*, which can be applied to any valid instances of the data types listed in (1), to retrieve or derive data from any parts of those structures in any combinations desired;
  - (3). A collection of *general integrity rules*, which implicitly or explicitly define the set of consistent database states or changes of state or both –-- these rules may sometimes be expressed as insert-update-delete rules

Data model

- A collection of concepts that can be used to describe *the structure of a database*
  - the data types, relationships, and constraints that should hold for the data
  - a set of basic operations for specifying retrievals and updates on the database
- To provide the necessary means to achieve some *level of abstraction* by hiding details of data storage that are not needed by most database users

Purposes of a data model

E. F. Codd. Data models in database management, ACM, 1980.

- 1. As a tool for specifying the kinds of data and data organization that are permissible in a specific database;
- 2. As a basis for developing a general design methodology for databases;
- 3. As a basis for coping with evolution of databases so as to have minimal logical impact on existing application programs and terminal activities;
- 4. As a basis for the development of families of very high level languages for query and data manipulation;
- 5. As a focus for DBMS architecture;
- 6. As a vehicle for research into the behavioral properties of alternative organizations of data.

Categories of data models

- *High-level* or *conceptual* data models
  - provide concepts that are close to the way many users perceive data
  - e.g. entity relationship model
- *Representational* or *implementation* data models
  - provide concepts that may be understood by end users but that are not too far removed from the way data is organized within the computer
  - hide some details of data storage
  - able to be implemented on a computer system in a direct way
  - e.g. relational data model, object-oriented data model
- *Low-level* or *physical* data models
  - provide concepts that describe the details of how data is stored in the computer

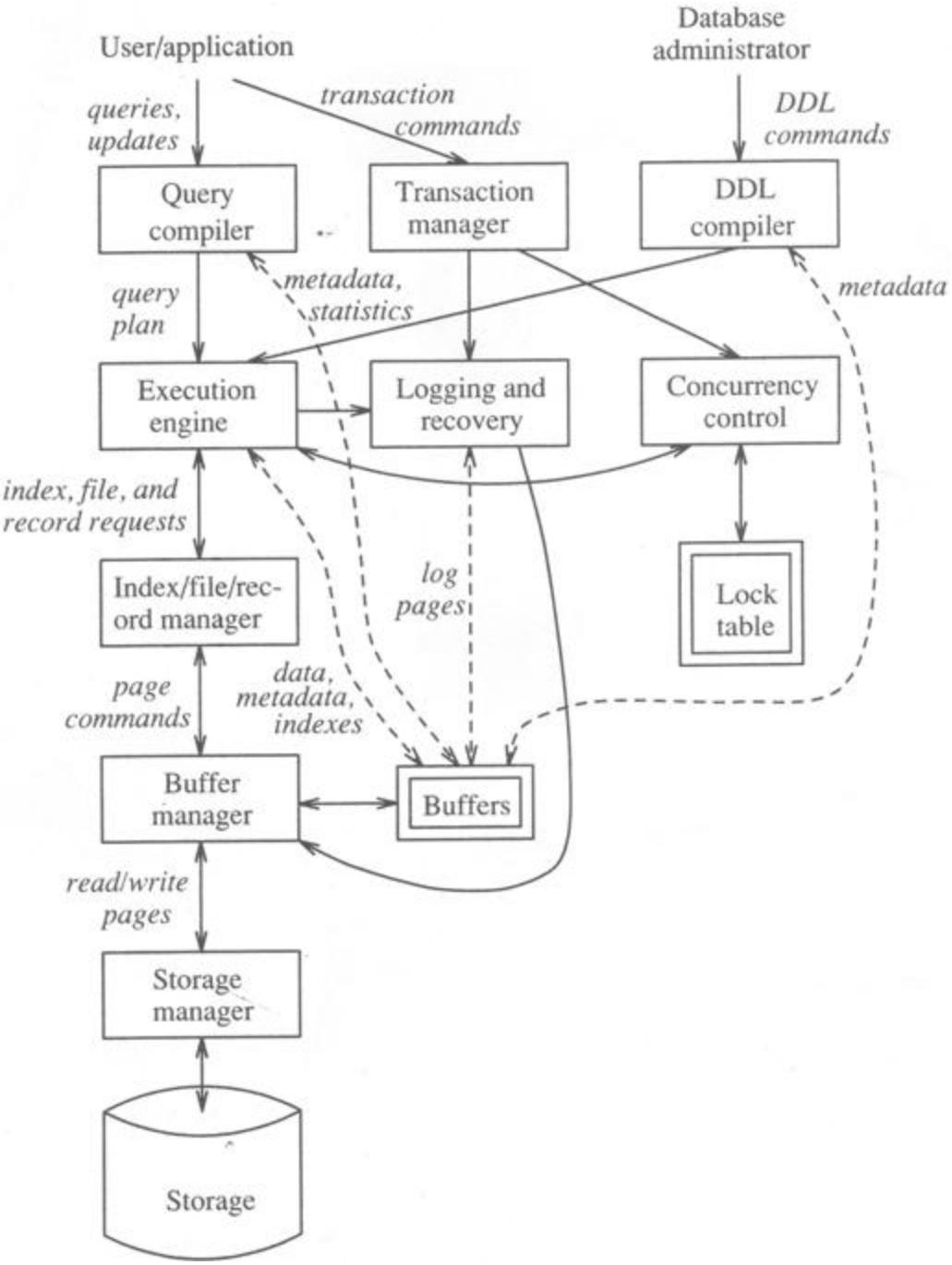
1.5. Database management systems

- a collection of programs that enables users to create and maintain a database
- a general-purpose software system that facilitates the processes of defining, constructing, manipulating, and sharing databases among various users and applications

Database management systems

- *Defining* a database involves specifying the data types, structures, and constraints for the data to be stored in the database.
- *Constructing* the database is the process of storing the data itself on some storage medium that is controlled by the DBMS.
- *Manipulating* a database includes such functions as querying the database to retrieve specific data, updating the database to reflect changes in the miniworld, and generating reports from the data.
- *Sharing* a database allows multiple users and programs to access the database concurrently.
- *Protection* includes both system protection against hardware or software malfunction (or crashes), and security protection against unauthorized or malicious access.
- A typical large database may have a life cycle of many years, so the DBMS must be able to *maintain* the database system by allowing the system to evolve as requirements change over time.

DBMS components



system component

in-memory structure

control/data flow

data flow

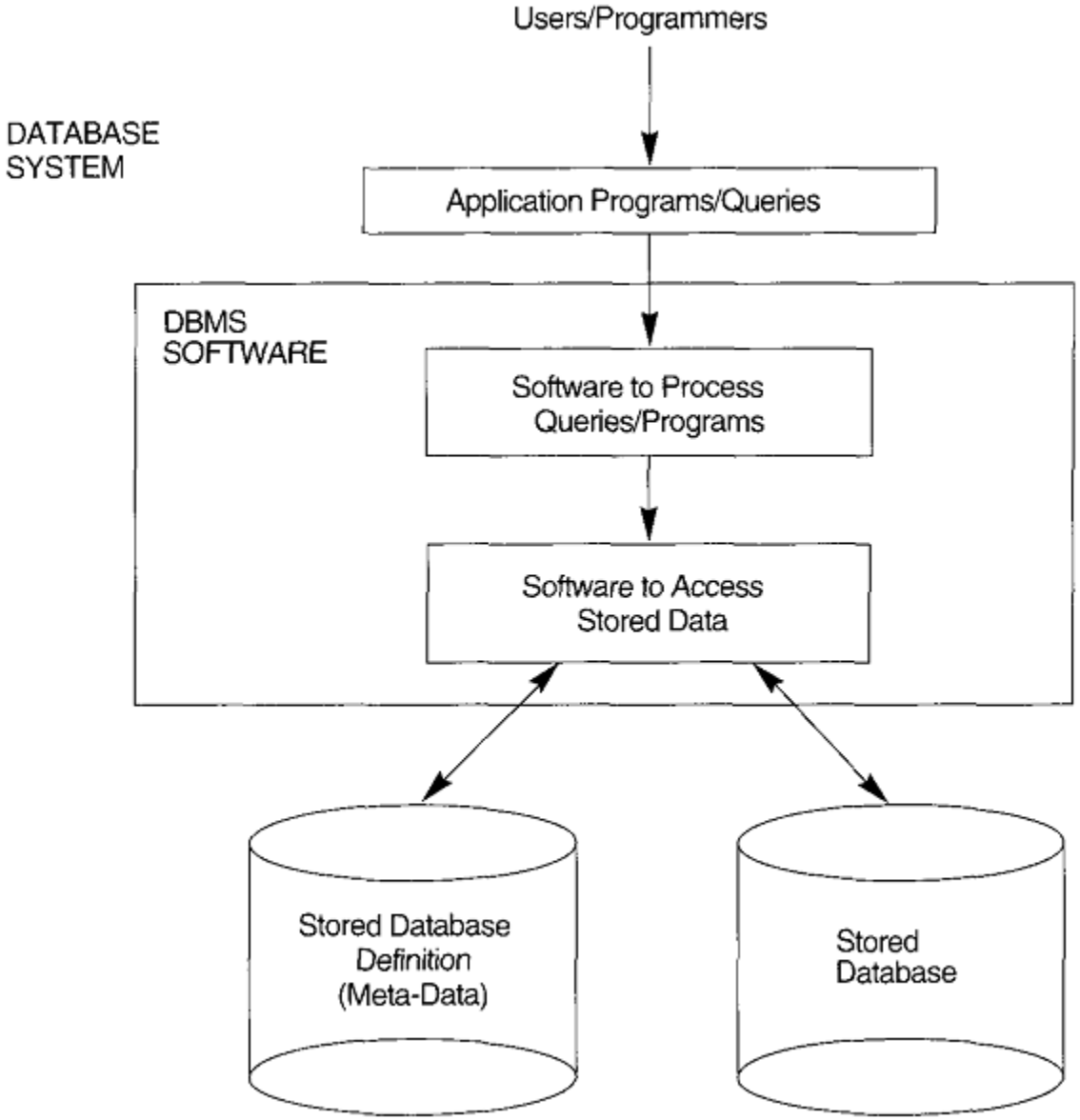
History of DBMS development

- 1960s, navigational DBMSs
  - IBM's IMS with the hierarchical model,
  - IDMS with the CODASYL network model, …
- 1970s-late 1980s, relational DBMSs with SQL
  - Oracle,
  - MS SQL Server,
  - IBM's DB2,
  - MySQL, …
- 1990s, object-oriented DBMSs (object, object-relational)
  - Oracle,
  - PostgreSQL,
  - Informix, …
- 2000s, NoSQL and NewSQL
  - XML DBMSs: Oracle Berkely DB XML, …
  - NoSQL DBMSs: MongoDB, Hbase, Cassandra, …
  - NewSQL DBMSs: ScaleBase, VoltDB, …

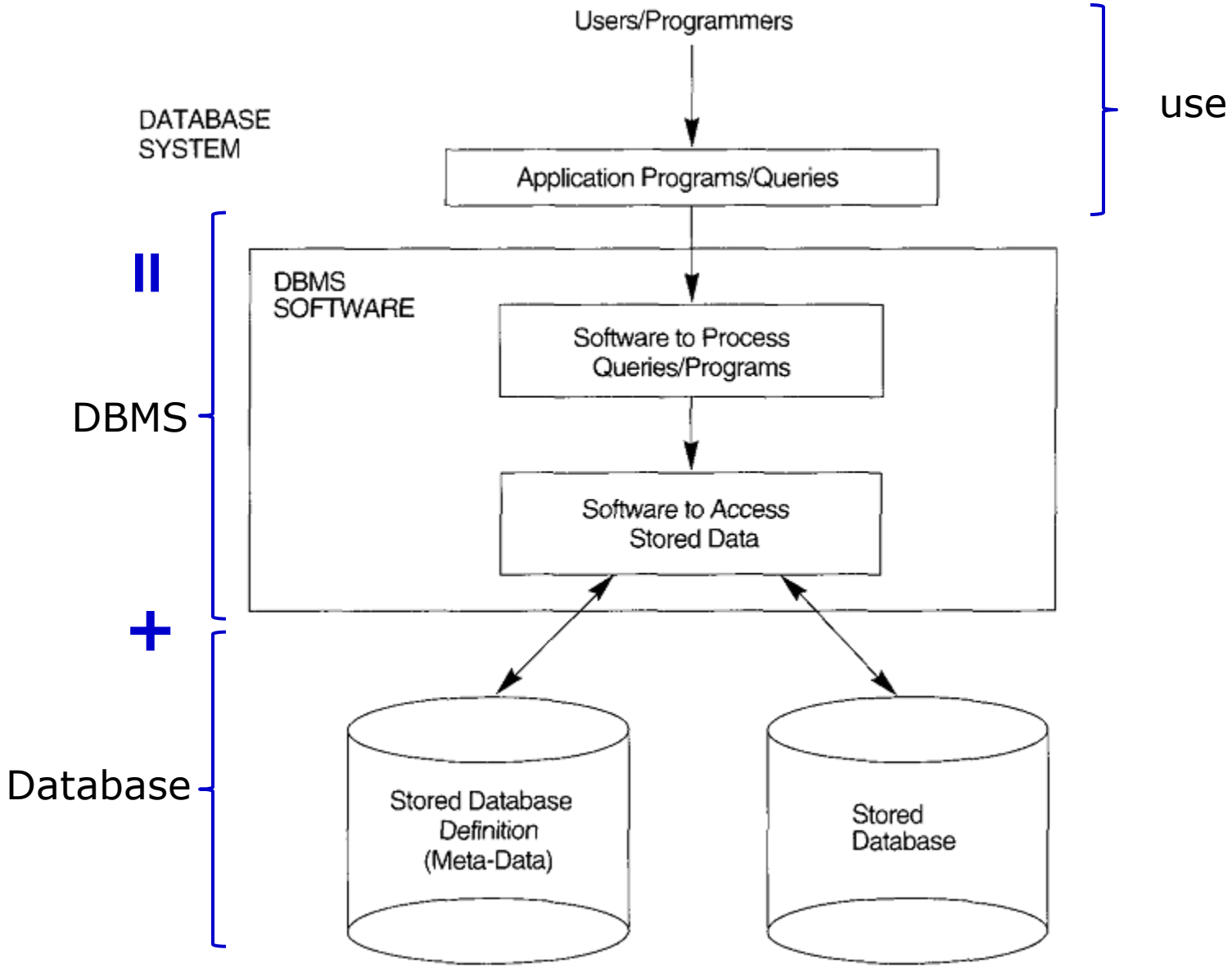
Database management system

- When *not* to use
  - Unnecessary overhead costs of using a DBMS
    - High initial investment in hardware, software, and training
    - The generality that a DBMS provides for defining and processing data
    - Overhead for providing security, concurrency control, recovery, and integrity functions
  - The database and applications are simple, well defined, and not expected to change.
  - There are stringent real-time requirements for some programs that may not be met because of DBMS overhead.
  - Multiple-user access to data is not required.

A simplified database system environment



A simplified database system environment

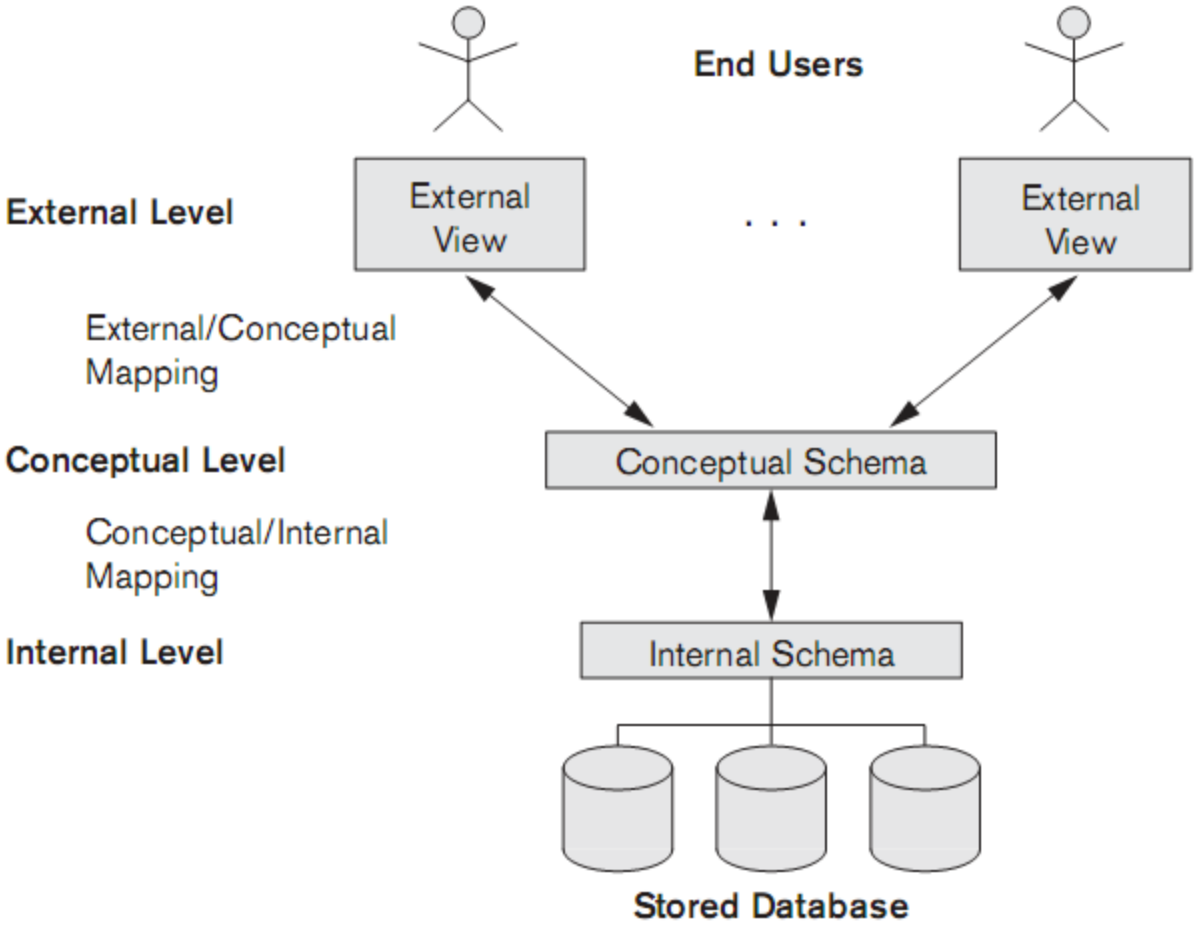


1.6. Database systems

Database system = database + DBMS

- Database: data modeling
- Database management system (DBMS): functionalities
  - File organization & indexing
  - Query processing & optimization
  - Database security
  - Transaction processing & concurrency control
  - Backup & recovery

The Three-Schema Architecture



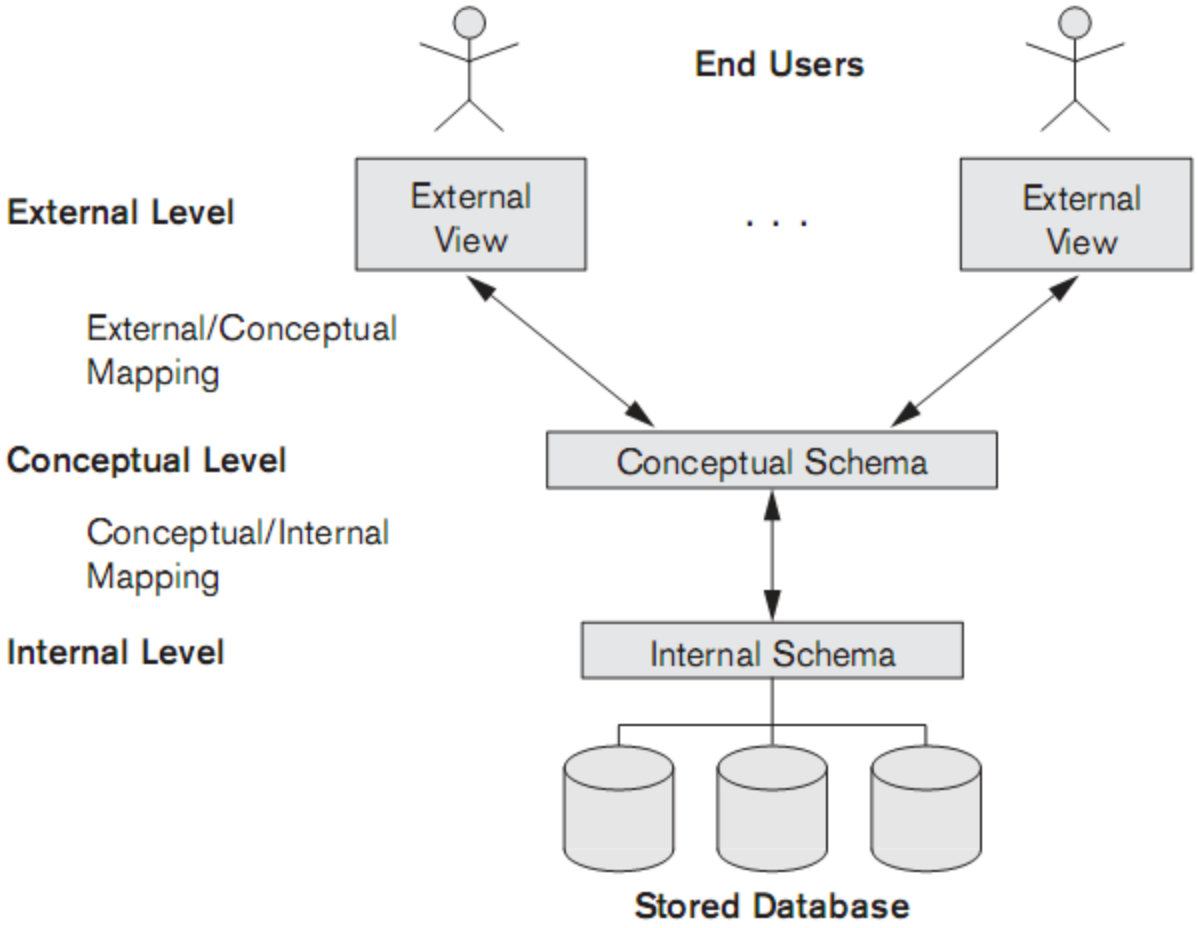
The three-schema architecture

The Three-Schema Architecture

the part of the database that a particular user group is interested in and hides the rest of the database from that user group

the structure of the whole database for a community of users

the physical storage structure of the database



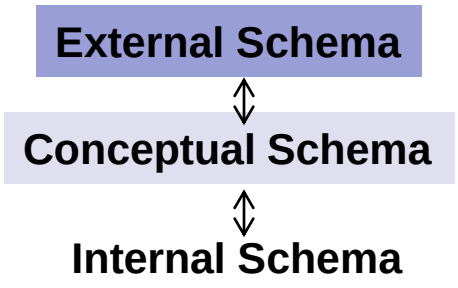
The three-schema architecture

The Three-Schema Architecture

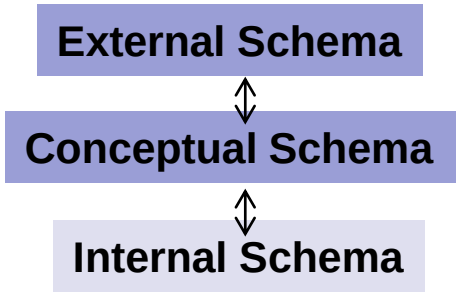
- The three-schema architecture
  - An *internal schema* describes the physical storage structure of the database.
  - A *conceptual schema* is a high-level description of the whole database.
  - *External schemas* describe the views of different user groups.
- Data independence
  - Data Independence is the capacity to change the schema at one level of a database system without having to change the schema at the next higher level.
  - *Logical* data independence & *Physical* data independence

The Three-Schema Architecture

- Data independence
  - *Logical* data independence: the capacity to change the *conceptual* schema without having to change *external* schemas or application programs
  - *Physical* data independence: the capacity to change the *internal* schema without having to change the *conceptual* schema



Logical Data Independence



Physical Data Independence

Characteristics of database systems

- Self-describing nature of a database system
- Insulation between programs and data, and data abstraction
- Support of multiple views of the data
- Sharing of data and multiuser transaction processing
- Controlling redundancy
- Restricting unauthorized access
- Providing persistent storage for program objects

Characteristics of database systems

- Providing storage structures for efficient query processing
- Providing backup and recovery
- Providing multiple user interfaces
- Representing complex relationships among data
- Enforcing integrity constraints
- Permitting inferencing and actions using rules

Characteristics of database systems

- Potential for enforcing standards
- Reduced application development time
- Flexibility
- Availability of up-to-date information
- Economies of scale

Classification of database systems

- Based on data models (widely-used)
- Based on kinds of data
- Based on data storage and organization
- Based on architectures
- Based on the number of users

Classification of database systems

- Based on data models (widely-used)
  - Relational database systems
  - Object-oriented database systems
  - Object relational database systems
  - XML-enabled database systems
  - XML native database systems
  - Graph database systems
  - …

Classification of database systems

- Based on kinds of data
  - Traditional database systems (simple data)
  - Multimedia database systems
  - Spatial database systems
  - Temporal database systems
  - Spatiotemporal database systems
  - Inductive database systems
  - Deductive database systems

Classification of database systems

- Based on data storage and organization
  - Traditional database systems
  - In-memory database systems
  - Columnar database systems

Classification of database systems

- Based on architectures
  - Centralized database systems
  - Distributed database systems
  - Parallel database systems

Classification of database systems

- Based on the number of users
  - Single-user database systems
  - Multi-user database systems

  → The number of users who can use the system concurrently – that is, at the same time

1.7. Applications of database systems

- In any organization, in any application domain where there is a need:
  - A large database
  - A multiuser environment
- Providing application flexibility with relational databases
- Object-oriented applications and the need for more complex databases
- Interchanging data on the Web for e-commerce
- Extending database capabilities for new applications

1.7. Applications of database systems

- *Scientific applications* that store large amounts of data resulting from scientific experiments in areas such as high-energy physics or the mapping of the human genome.
- Storage and retrieval of *images*, from scanned news or personal photographs to satellite photograph images and images from medical procedures such as X-rays or MRI (magnetic resonance imaging).
- Storage and retrieval of *videos*, such as movies, or video clips from news or personal digital cameras.
- *Data mining applications* that analyze large amounts of data searching for the occurrences of specific patterns or relationships.
- *Spatial applications* that store spatial locations of data such as weather information or maps used in geographical information systems.
- *Time series applications* that store information such as economic data at regular points in time, for example, daily sales or monthly gross national product figures.

→ *NEED*: more complex data structures, new data types, new operations and query language constructs, new storage and indexing structures

→ *New general/special purpose functionalities* added to a database system

Summary

- Database system = database + database management system
  - Database
    - Data/ metadata → information/ knowledge
    - Data model (conceptual, logical)
  - Database management system
    - Three-schema architecture & data independence
    - Functionalities
- Characteristics, classification, and applications of database systems
- File processing systems vs. Database systems

Chapter 1: Overall Introduction to Database Systems

Review

- 1.1. Define the following terms: data, database, data model, DBMS, database system, program-data independence, metadata, transaction-processing application.
- 1.3. Discuss the main characteristics of the database approach and how it differs from traditional file systems.
- 1.6. Discuss the capabilities that should be provided by a DBMS.
- 1.8. What is the difference between controlled and uncontrolled redundancy?

Review

- 2.2. Discuss the main categories of data models.
- 2.3. What is the difference between a database schema and a database state?
- 2.4. Describe the three-schema architecture. Why do we need mappings between schema levels?
- 2.5. What is the difference between logical data independence and physical data independence?
- 2.10. Discuss some types of database utilities and tools and their functions.

Next
Chapter 2: The Entity-Relationship Model

- 2.1. Database design process from conceptual modeling
- 2.2. Conceptual data modeling
- 2.3. The entity-relationship model
- 2.4. The extended entity-relationship model