The National Higher School of Artificial Intelligence
المدرسة الوطنية العليا للذكاء الاصطناعي

The National Higher School of Artificial Intelligence

DATABASES

Chapter 1 : DataBase Systems

Pr. Kamel BOUKHALFA

Slides From the Textbook :
Carlos Coronel and Steven Morris, Database Systems: Design, Implementation, and Management
Tenth Edition

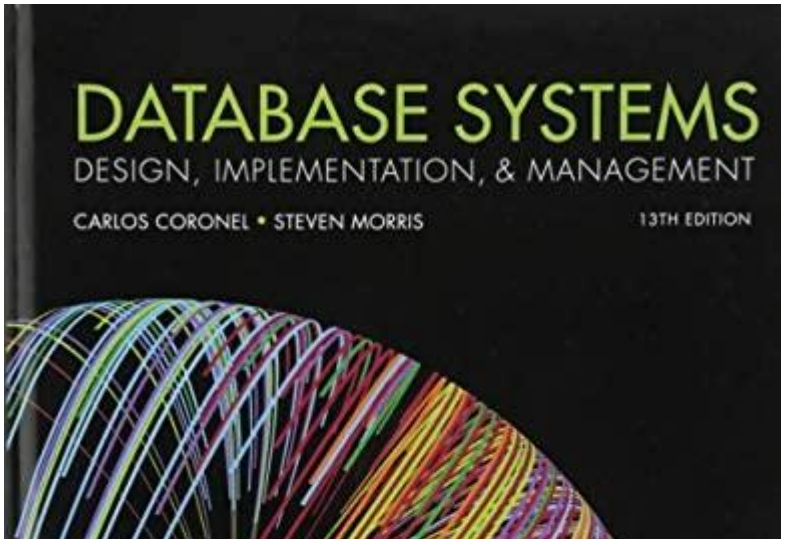
Presentation

- Kamel Boukhalfa
- Phd From USTHB, Algiers, Algeria/ENSMA, Poitiers, France (2009)
- Full Professor, USTHB (2017)
- Full Professor, National Higher School of Artificial Intelligence (2021)
- **Teaching :** Databases, Big Data, Datamining, C++ Programming, etc.
- **Research Areas:** Big Data, Data Warehousing, Metaheuristics, Data mining, Cloud Computing, Social Networks
- **Emails** : kamel.boukhalfa@ensia.edu.dz
- **Personnel website** : http://boukhalfa.jimdo.com

Information About the course

Course Description :
The object of this course is to teach students the **general concepts of relational databases** and how to **design a database** that is anomaly free. Students will learn to **design**, **create**, **populate**, and **query** a database by working with a relational database engine and the **SQL language**. Students will also learn basic **database administration** skills such as creating users, granting/revoking privileges individually or collectively to several users through the use of roles. Further, students will learn how to create **constraints** with **triggers** in addition to the use of **PL/SQL language**.

Prerequisite : Programming, Data Structures
Evaluation Method : Coursework (60%) + Final Exam (40%)



1. **Database Systems**
2. **Relational Database Model**
3. **Entity Relationship (ER) Modelling**
4. **Normalisation of Database Tables**
5. **Introduction to Structured Query Language (SQL)**
6. **Advanced SQL (LABS)**
7. **Transaction Management and Concurrency Control**

References

1. Carlos Coronel and Steven Morris. Database Systems: Design, Implementation, & Management, 13th Edition, 2018.
2. Raghu Ramakrishnan, Johannes Gehrke. Database Management Systems, McGraw-Hill Higher Education; 3rd edition. 2002
3. Ramez Elmasri, Shamkant B. Navathe. Fundam, Fundamentals of Database Systems, Pearson; 7th edition, 2015

Evaluation

A) Course Test (30 mn) – 5%

B) Tutorial Test (60 mn) – 10%

C) LABS Test (60 mn) – 10%

D) Midterm Test (90 mn) - 15%

E) Final Exam (90 mn) : 60%

Objectives

In this chapter, you will learn

- The difference between **data** and **information**
- What a database is, the various types of databases, and why they are valuable assets for decision making
- The importance of database design
- How modern databases evolved from file systems

Objectives (cont'd.)

- About flaws in file system data management
- The main components of the database system
- The main functions of a database management system (DBMS)

Introduction

- Good decisions require good information derived from raw facts
- Data is managed most efficiently when stored in a database
- Databases evolved from computer file systems
- Understanding file system characteristics is important

Why Databases?

- Databases solve many of the problems encountered in data management
  - Used in almost all modern settings involving data management:
    - Business
    - Research
    - Administration
- Important to understand how databases work and interact with other applications

Data vs. Information

- Data are raw facts
- Information is the result of processing raw data to reveal meaning
- Information requires context to reveal meaning
- Raw data must be formatted for storage, processing, and presentation
- Data are the foundation of information, which is the bedrock of knowledge

Data vs. Information (cont'd.)

- **Data**: building blocks of information
- **Information** produced by processing data
- **Information** used to reveal meaning in data
- Accurate, relevant, timely information is the key to good decision making
- Good decision making is the key to organizational survival
- **Data management:** focuses on proper generation, storage, and retrieval of data

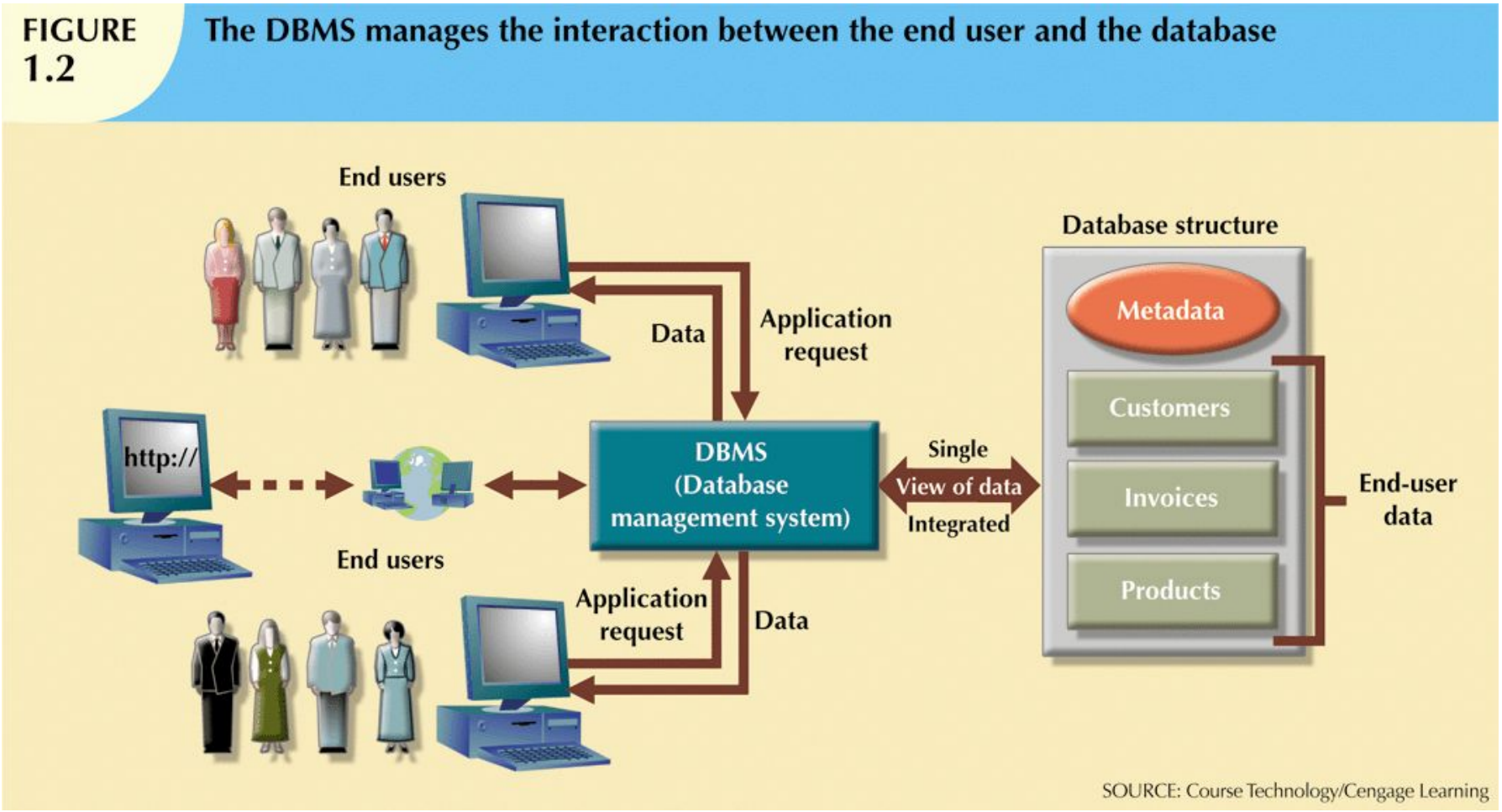
Introducing the Database

- **Database**: shared, integrated computer structure that stores a collection of:
  - **End-user data:** raw facts of interest to end user
  - **Metadata**: data about data
    - Provides description of data characteristics and relationships in data
    - Complements and expands value of data
- **Database management system (DBMS):** collection of programs
  - Manages structure and controls access to data

Role and Advantages of the DBMS

- **DBMS** is the intermediary between the user and the database
  - Database structure stored as file collection
  - Can only access files through the DBMS
- **DBMS** enables data to be shared
- **DBMS** integrates many users' views of the data

FIGURE 1.2 The DBMS manages the interaction between the end user and the database



Role and Advantages of the DBMS (cont'd.)

- Advantages of a DBMS
  - Improved data sharing
  - Improved data security
  - Better data integration
  - Minimized data inconsistency
  - Improved data access
  - Improved decision making
  - Increased end-user productivity

Types of Databases

- Databases can be classified according to:
  - Number of users
  - Database location(s)
  - Expected type and extent of use
- **Single-user database** supports only one user at a time
  - Desktop database: single-user; runs on PC
- **Multiuser database** supports multiple users at the same time
  - Workgroup and enterprise databases

Types of Databases (cont'd.)

- **Centralized database**: data located at a single site
- **Distributed database:** data distributed across several different sites
- **Operational database:** supports a company's day-to-day operations
  - Transactional or production database
- **Data warehouse:** stores data used for tactical or strategic decisions

Problems with File System Data Processing (cont'd.)

- Security features difficult to program
  - Often omitted in file system environments
- Summary of file system limitations:
  - Requires extensive programming
  - Cannot perform ad hoc queries
  - System administration is complex and difficult
  - Difficult to make changes to existing structures
  - Security features are likely to be inadequate

Types of Databases (cont'd.)

- **Unstructured** data exist in their original state
- **Structured** data result from formatting
  - Structure applied based on type of processing to be performed
- **Semistructured** data have been processed to some extent
- **Extensible Markup Language (XML)** represents data elements in textual format
  - XML database supports semistructured XML data

TABLE 1.1 Types of Databases

PRODUCT	NUMBER OF USERS			DATA LOCATION		DATA USAGE		XML
	SINGLE USER	MULTIUSER						
		WORKGROUP	ENTERPRISE	CENTRALIZED	DISTRIBUTED	OPERATIONAL	ANALYTICAL	
MS Access	X	X		X		X		
MS SQL Server	X[3]	X	X	X	X	X	X	X
IBM DB2	X[3]	X	X	X	X	X	X	X
MySQL	X	X	X	X	X	X	X	X
Oracle RDBMS	X[3]	X	X	X	X	X	X	X

[3] Vendor offers single-user/personal DBMS version

Why Database Design Is Important

- Database design focuses on design of database structure used for end-user data
  - Designer must identify database's expected use
- **Well-designed database**
  - Facilitates data management
  - Generates accurate and valuable information
- **Poorly designed database**
  - Causes difficult-to-trace errors

Evolution of File System Data Processing

- Reasons for studying file systems
  - Complexity of database design is easier to understand
  - Understanding file system problems helps to avoid problems with DBMS systems
  - Knowledge of file system is useful for converting file system to database system
- File systems typically composed of collection of file folders, each tagged and kept in cabinet
  - Organized by expected use

Evolution of File System Data Processing (cont'd.)

- Contents of each file folder are logically related
- **Manual file systems**
  - Served as a data repository for small data collections
  - Cumbersome for large collections
- **Computerized file systems**
  - Data processing (DP) specialist converted computer file structure from manual system
    - Wrote software that managed the data
    - Designed the application programs

Evolution of File System Data Processing (cont'd.)

- Initially, computer file systems resembled manual systems
- As number of files increased, file systems evolved
- Each file used its own application program to store, retrieve, and modify data
- Each file was owned by individual or department that commissioned its creation

FIGURE 1.5 Contents of the CUSTOMER file

C_NAME	C_PHONE	C_ADDRESS	C_ZIP	A_NAME	A_PHONE	TP	AMT	REN
Alfred A. Ramas	615-844-2573	218 Fork Rd., Babs, TN	36123	Leah F. Hahn	615-882-1244	T1	100.00	05-Apr-2012
Leona K. Dunne	713-894-1238	Box 12A, Fox, KY	25246	Alex B. Alby	713-228-1249	T1	250.00	16-Jun-2012
Kathy W. Smith	615-894-2285	125 Oak Ln, Babs, TN	36123	Leah F. Hahn	615-882-2144	S2	150.00	29-Jan-2013
Paul F. Olowski	615-894-2180	217 Lee Ln., Babs, TN	36123	Leah F. Hahn	615-882-1244	S1	300.00	14-Oct-2012
Myron Orlando	615-222-1672	Box 111, New, TN	36155	Alex B. Alby	713-228-1249	T1	100.00	28-Dec-2012
Amy B. O'Brian	713-442-3381	387 Troll Dr., Fox, KY	25246	John T. Okon	615-123-5589	T2	850.00	22-Sep-2012
James G. Brown	615-297-1228	21 Tye Rd., Nash, TN	37118	Leah F. Hahn	615-882-1244	S1	120.00	25-Mar-2013
George Williams	615-290-2556	155 Maple, Nash, TN	37119	John T. Okon	615-123-5589	S1	250.00	17-Jul-2012
Anne G. Farriss	713-382-7185	2119 Elm, Crew, KY	25432	Alex B. Alby	713-228-1249	T2	100.00	03-Dec-2012
Olette K. Smith	615-297-3809	2782 Main, Nash, TN	37118	John T. Okon	615-123-5589	S2	500.00	14-Mar-2013

C_NAME = Customer name
C_PHONE = Customer phone
C_ADDRESS = Customer address
C_ZIP = Customer zip code

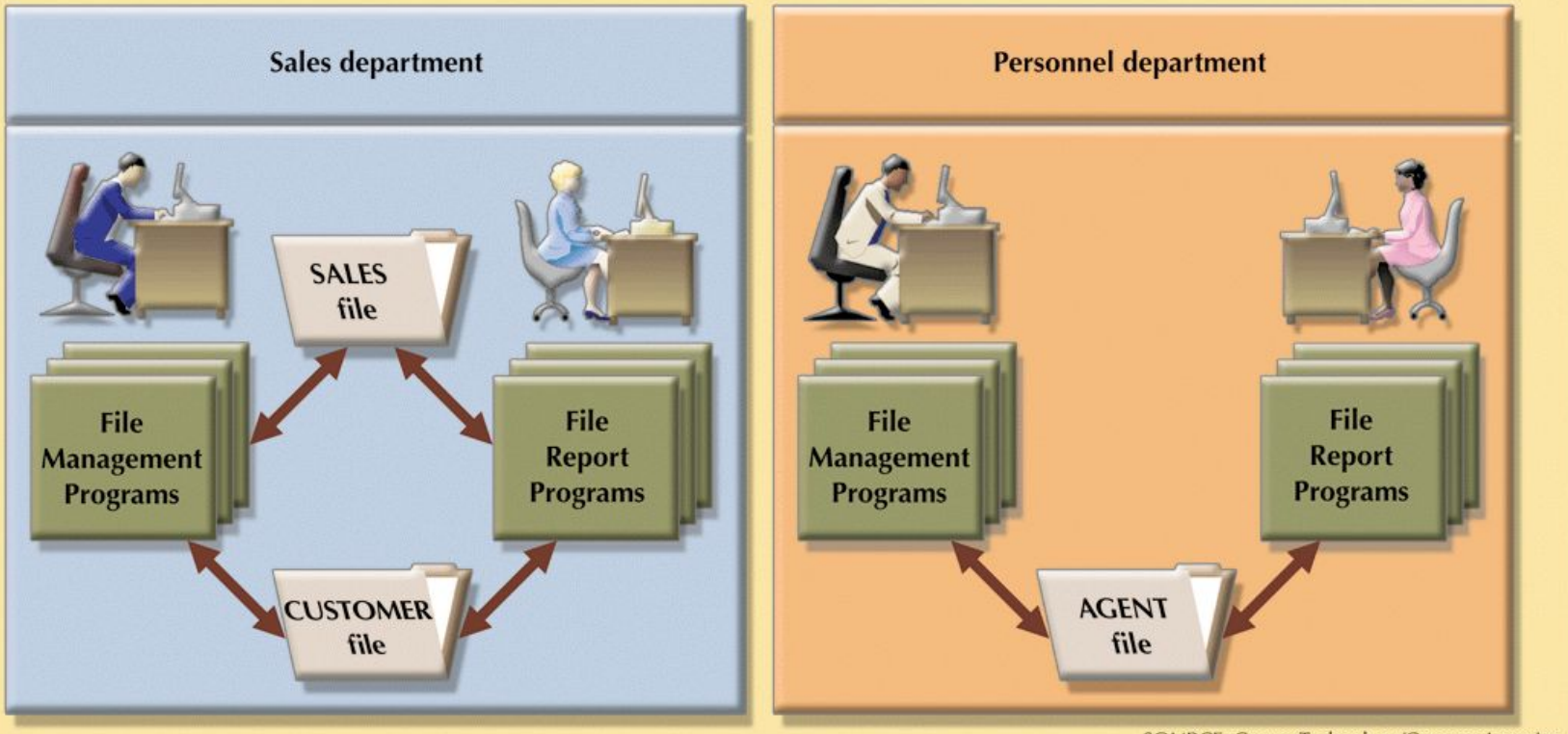
A_NAME = Agent name
A_PHONE = Agent phone
TP = Insurance type
AMT = Insurance policy amount, in thousands of $
REN = Insurance renewal date

SOURCE: Course Technology/Cengage Learning

TABLE 1.2 Basic File Terminology

TERM	DEFINITION
Data	Raw facts, such as a telephone number, a birth date, a customer name, and a year-to-date (YTD) sales value. Data have little meaning unless they have been organized in some logical manner.
Field	A character or group of characters (alphabetic or numeric) that has a specific meaning. A field is used to define and store data.
Record	A logically connected set of one or more fields that describes a person, place, or thing. For example, the fields that constitute a customer record might consist of the customer's name, address, phone number, date of birth, credit limit, and unpaid balance.
File	A collection of related records. For example, a file might contain data about the students currently enrolled at Gigantic University.

FIGURE 1.7 A simple file system



File System: Modern End-User Productivity Tools

- Ubiquitous use of personal productivity tools can introduce the same problems as the old file systems
- Microsoft Excel
  - Widely used by business users
  - Users have become so adept at working with spreadsheets, they tend to use them to complete tasks for which spreadsheets are not appropriate – database substitute

Problems with File System Data Processing

- File systems were an improvement over manual system
  - File systems used for more than two decades
  - Understanding the shortcomings of file systems aids in development of modern databases
  - Many problems not unique to file systems
- Even simple file system retrieval task required extensive programming
  - Ad hoc queries impossible
  - Changing existing structure difficult

Structural and Data Dependence

- **Structural dependence**: access to a file is dependent on its own structure
  - All file system programs must be modified to conform to a new file structure
- **Structural independence:** change file structure without affecting data access
- **Data dependence:** data access changes when data storage characteristics change
- **Data independence:** data storage characteristics do not affect data access

Structural and Data Dependence (cont'd.)

- Practical significance of data dependence is difference between logical and physical format
- **Logical data format:** how human views the data
- **Physical data format:** how computer must work with data
- Each program must contain
  - Lines specifying opening of specific file type
  - Record specification
  - Field definitions

Data Redundancy

- File system structure makes it difficult to combine data from multiple sources
  - Vulnerable to security breaches
- Organizational structure promotes storage of same data in different locations
  - Islands of information
- Data stored in different locations is unlikely to be updated consistently
- Data redundancy: same data stored unnecessarily in different places

Data Redundancy (cont'd.)

- Data inconsistency: different and conflicting versions of same data occur at different places
- Data anomalies: abnormalities when all changes in redundant data are not made correctly
  - Update anomalies: An agent has a new phone number, it must be changed in all records of that agent
  - Insertion anomalies: A new agent would have to be entered with a dummy customer
  - Deletion anomalies: Deleting a customer may delete the only record of an agent

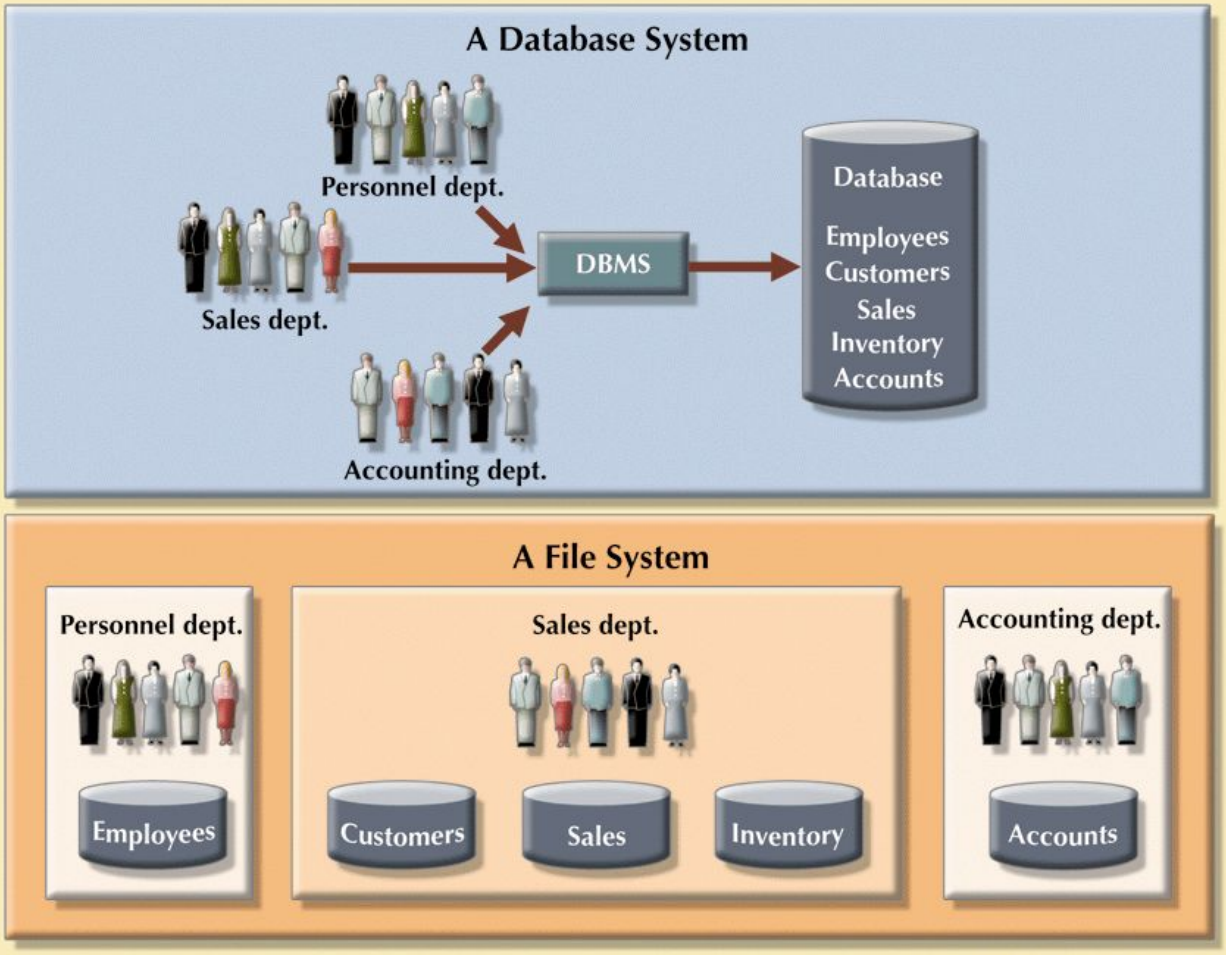
Lack of Design and Data-Modeling Skills

- Most users lack the skill to properly design databases
  - Despite multiple personal productivity tools being available
- Data-modeling skills
  - Vital in the data design process
- Good data modeling facilitates communication between the designer, user, and the developer

Database Systems

- Database system consists of logically related data stored in a single logical data repository
  - May be physically distributed among multiple storage facilities
  - DBMS eliminates most of file system's problems
  - Current generation stores data structures, relationships between structures, and access paths
    - Also defines, stores, and manages all access paths and components

FIGURE 1.8 Contrasting database and file systems

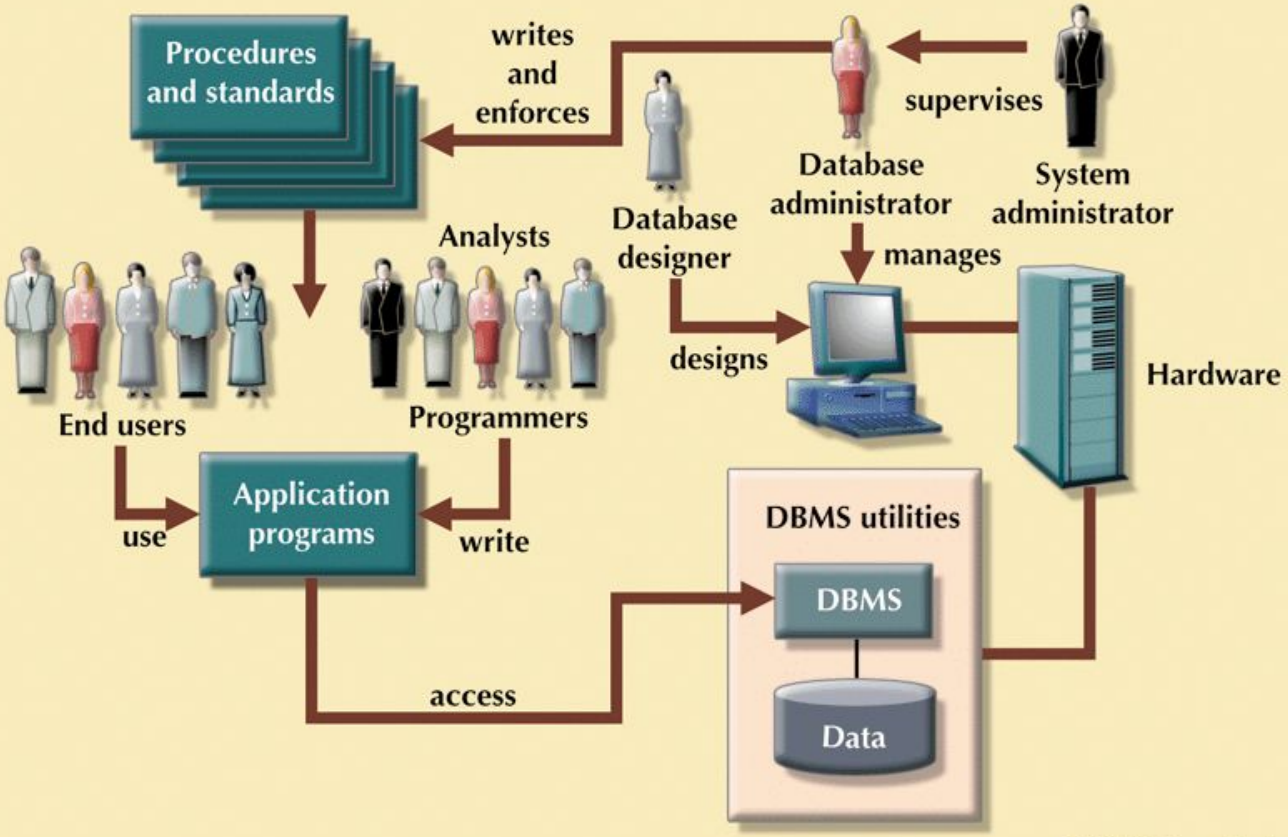


SOURCE: Course Technology/Cengage Learning

The Database System Environment

- **Database system:** defines and regulates the collection, storage, management, use of data
- Five major parts of a database system:
  - Hardware
  - Software
  - People
  - Procedures
  - Data

FIGURE 1.9 The database system environment



SOURCE: Course Technology/Cengage Learning

The Database System Environment (cont'd.)

- **Hardware**: all the system's physical devices
- **Software**: three types of software required
  - Operating system software
  - DBMS software
  - Application programs and utility software

The Database System Environment (cont'd.)

- **People**: all users of the database system
  - System and database administrators
  - Database designers
  - Systems analysts and programmers
  - End users
- **Procedures**: instructions and rules that govern the design and use of the database system
- **Data**: the collection of facts stored in the database

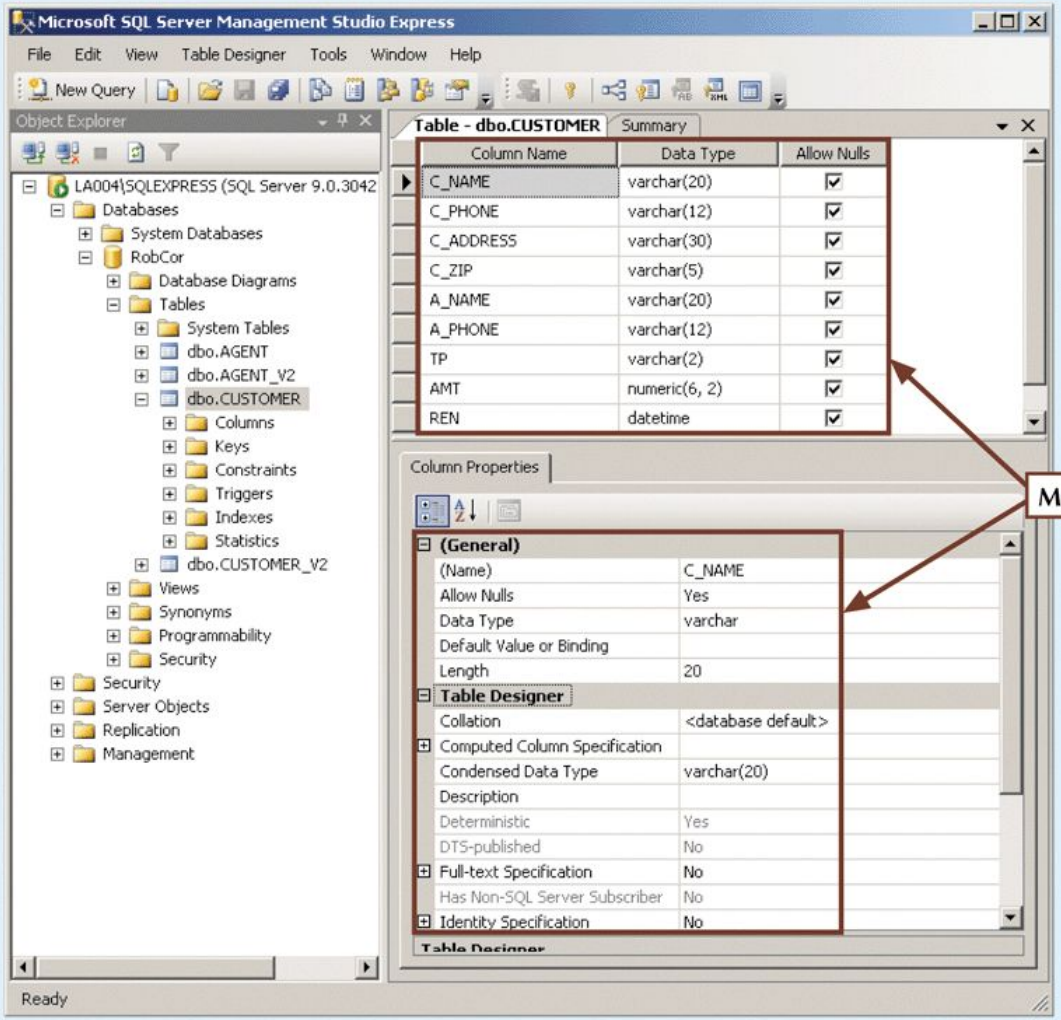
The Database System Environment (cont'd.)

- Database systems are created and managed at different levels of complexity
- Database solutions must be cost-effective as well as tactically and strategically effective
- Database technology already in use affects selection of a database system

DBMS Functions

- Most functions are transparent to end users
  - Can only be achieved through the DBMS
- Data dictionary management
  - DBMS stores definitions of data elements and relationships (metadata) in a data dictionary
  - DBMS looks up required data component structures and relationships
  - Changes automatically recorded in the dictionary
  - DBMS provides data abstraction and removes structural and data dependency

FIGURE 1.10 Illustrating metadata with Microsoft SQL Server Express

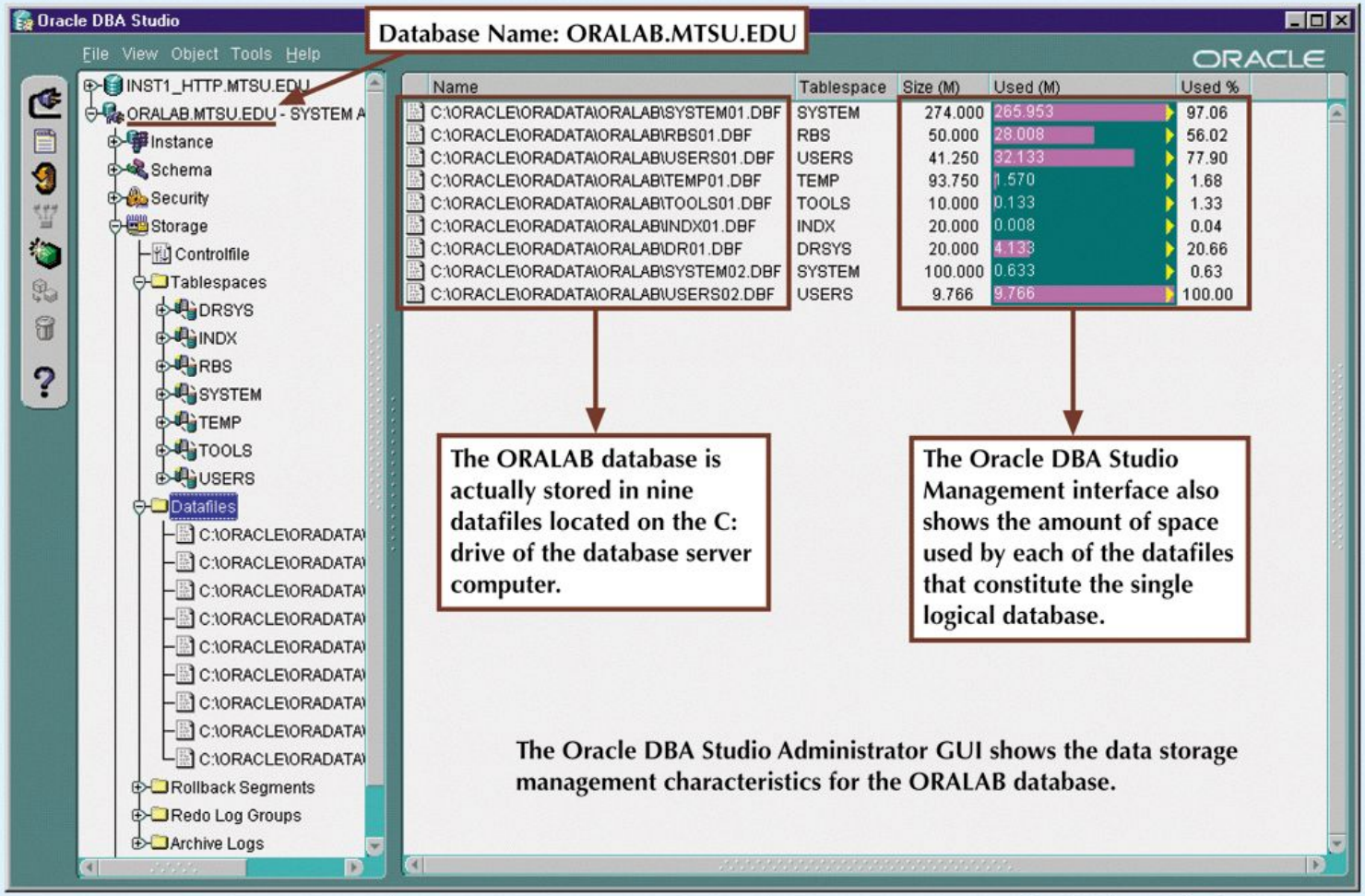


SOURCE: Course Technology/Cengage Learning

DBMS Functions (cont'd.)

- **Data storage management**
  - DBMS creates and manages complex structures required for data storage
  - Also stores related data entry forms, screen definitions, report definitions, etc.
  - **Performance tuning:** activities that make the database perform more efficiently
  - DBMS stores the database in multiple physical data files

FIGURE 1.11 Illustrating data storage management with Oracle



SOURCE: Course Technology/Cengage Learning

DBMS Functions (cont'd.)

- **Data transformation and presentation**
  - DBMS transforms data entered to conform to required data structures
  - DBMS transforms physically retrieved data to conform to user's logical expectations
- **Security management**
  - DBMS creates a security system that enforces user security and data privacy
  - Security rules determine which users can access the database, which items can be accessed, etc.

DBMS Functions (cont'd.)

- **Multi-User access control**
  - DBMS uses sophisticated algorithms to ensure concurrent access does not affect integrity
- **Backup and recovery management**
  - DBMS provides backup and data recovery to ensure data safety and integrity
  - Recovery management deals with recovery of database after a failure
    - Critical to preserving database's integrity

DBMS Functions (cont'd.)

- **Data integrity management**
  - DBMS promotes and enforces integrity rules
    - Minimizes redundancy
    - Maximizes consistency
  - Data relationships stored in data dictionary used to enforce data integrity
  - Integrity is especially important in transaction-oriented database systems

DBMS Functions (cont'd.)

- Database access languages and application programming interfaces
  - DBMS provides access through a query language
  - Query language is a nonprocedural language
  - Structured Query Language (SQL) is the de facto query language
    - Standard supported by majority of DBMS vendors

DBMS Functions (cont'd.)

- Database communication interfaces
  - Current DBMSs accept end-user requests via multiple different network environments
  - Communications accomplished in several ways:
    - End users generate answers to queries by filling in screen forms through Web browser
    - DBMS automatically publishes predefined reports on a Web site
    - DBMS connects to third-party systems to distribute information via e-mail

Managing the Database System: A Shift in Focus

- Database system provides a framework in which strict procedures and standards enforced
  - Role of human changes from programming to managing organization's resources
- Database system enables more sophisticated use of the data
- Data structures created within the database and their relationships determine effectiveness

Managing the Database System: A Shift in Focus (cont'd.)

- **Disadvantages of database systems:**
  - Increased costs
  - Management complexity
  - Vendor dependence
  - Frequent upgrade/replacement cycles

Preparing for Your Database Professional Career

TABLE 1.3 Database Career Opportunities

JOB TITLE	DESCRIPTION	SAMPLE SKILLS REQUIRED
Database developer	Creates and maintains database-based applications	Programming, database fundamentals, SQL
Database designer	Designs and maintains databases	Systems design, database design, SQL
Database administrator	Manages and maintains DBMS and databases	Database fundamentals, SQL, vendor courses
Database analyst	Develops databases for decision support reporting	SQL, query optimization, data warehouses
Database architect	Designs and implements database environments (conceptual, logical, and physical)	DBMS fundamentals, data modeling, SQL, hardware knowledge
Database consultant	Helps companies leverage database technologies to improve business processes and achieve specific goals	Database fundamentals, data modeling, database design, SQL, DBMS, hardware, vendor-specific technologies
Database security officer	Implements security policies for data administration	DBMS fundamentals, database administration, SQL, data security technologies

Summary

- Data are raw facts
- Information is the result of processing data to reveal its meaning
- Accurate, relevant, and timely information is the key to good decision making
- Data are usually stored in a database
- DBMS implements a database and manages its contents

Summary (cont'd.)

- Metadata is data about data
- Database design defines the database structure
  - Well-designed database facilitates data management and generates valuable information
  - Poorly designed database leads to bad decision making and organizational failure
- Databases evolved from manual and computerized file systems

Summary (cont'd.)

- In a file system, data stored in independent files
  - Each requires its own management program
- Some limitations of file system data management:
  - Requires extensive programming
  - System administration is complex and difficult
  - Changing existing structures is difficult
  - Security features are likely inadequate
  - Independent files tend to contain redundant data
    - Structural and data dependency problems

Summary (cont'd.)

- Database management systems were developed to address file system's inherent weaknesses
- DBMS present database to end user as single repository
  - Promotes data sharing
  - Eliminates islands of information
- DBMS enforces data integrity, eliminates redundancy, and promotes security