



Database System (Introduction)

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Introduction

- Purpose of Database Systems
- View of Data
- Database Languages
- Relational Databases
- Database Design
- Object-based and semistructured databases
- Data Storage and Querying
- Transaction Management
- Database Architecture
- Database Users and Administrators
- Overall Structure
- History of Database Systems



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Database Management System (DBMS)

- DBMS contains information about a particular enterprise
 - Collection of interrelated data
 - Set of programs to access the data
 - An environment that is both *convenient* and *efficient* to use
- Database Applications:
 - Banking: all transactions
 - Airlines: reservations, schedules
 - Universities: registration, grades
 - Sales: customers, products, purchases
 - Online retailers: order tracking, customized recommendations
 - Manufacturing: production, inventory, orders, supply chain
 - Human resources: employee records, salaries, tax deductions
- Databases touch all aspects of our lives



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Purpose of Database Systems

- In the early days, database applications were built directly on top of file systems
- Drawbacks of using file systems to store data:
 - Data redundancy and inconsistency
 - Multiple file formats, duplication of information in different files
 - Difficulty in accessing data
 - Need to write a new program to carry out each new task
 - Data isolation — multiple files and formats
 - Integrity problems
 - Integrity constraints (e.g. account balance > 0) become "buried" in program code rather than being stated explicitly
 - Hard to add new constraints or change existing ones



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Purpose of Database Systems (Cont.)

- Drawbacks of using file systems (cont.)
 - Atomicity of updates
 - Failures may leave database in an inconsistent state with partial updates carried out
 - Example: Transfer of funds from one account to another should either complete or not happen at all
 - Concurrent access by multiple users
 - Concurrent access needed for performance
 - Uncontrolled concurrent accesses can lead to inconsistencies
 - Example: Two people reading a balance and updating it at the same time
 - Security problems
 - Hard to provide user access to some, but not all, data
- Database systems offer solutions to all the above problems

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Levels of Abstraction

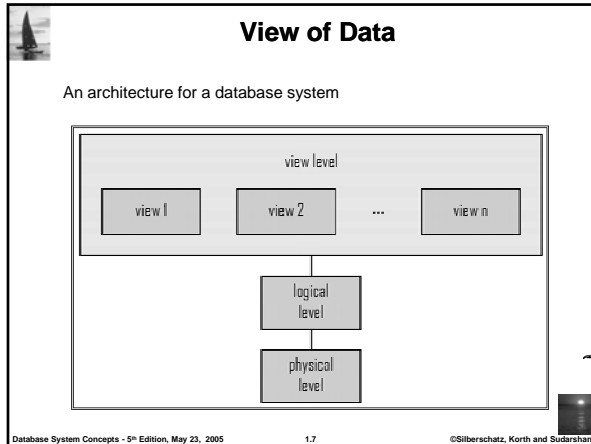
- **Physical level:** describes how a record (e.g., customer) is stored.
- **Logical level:** describes data stored in database, and the relationships among the data.


```

type customer = record
  customer_id : string;
  customer_name : string;
  customer_street : string;
  customer_city : integer;
end;
      
```
- **View level:** application programs hide details of data types. Views can also hide information (such as an employee's salary) for security purposes.

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- ## Instances and Schemas
- Similar to types and variables in programming languages
 - **Schema** – the logical structure of the database
 - Example: 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**: database design at the physical level
 - **Logical schema**: database design at the logical level
 - **Instance** – the actual content of the database at a particular point in time
 - Analogous to the value of a variable
 - **Physical Data Independence** – the ability to modify the physical schema without changing the logical schema
 - Applications depend on 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.
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- ## Data Models
- A collection of tools for describing
 - Data
 - Data relationships
 - Data semantics
 - Data constraints
 - Relational model
 - Entity-Relationship data model (mainly for database design)
 - Object-based data models (Object-oriented and Object-relational)
 - Semistructured data model (XML)
 - Other older models:
 - Network model
 - Hierarchical model
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- ## Data Manipulation Language (DML)
- Language for accessing and manipulating the data organized by the appropriate data model
 - DML also known as query language
 - Two classes of languages
 - **Procedural** – user specifies what data is required and how to get those data
 - **Declarative (nonprocedural)** – user specifies what data is required without specifying how to get those data
 - SQL is the most widely used query language
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- ## Data Definition Language (DDL)
- Specification notation for defining the database schema

Example: `create table account (`
 `account-number char(10),`
 `balance integer)`
 - 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 used
 - Integrity constraints
 - Domain constraints
 - Referential integrity (**references** constraint in SQL)
 - Assertions
 - Authorization
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Relational Model

Attributes

- Example of tabular data in the relational model

customer_id	customer_name	customer_street	customer_city	account_number
192-83-7465	Johnson	12 Alma St.	Palo Alto	A-101
192-83-7465	Johnson	12 Alma St.	Palo Alto	A-201
677-89-9011	Hayes	3 Main St.	Harrison	A-102
182-73-6091	Turner	123 Putnam St.	Stamford	A-305
321-12-3123	Jones	100 Main St.	Harrison	A-217
336-66-9999	Lindsay	175 Park Ave.	Pittsfield	A-222
019-28-3746	Smith	72 North St.	Rye	A-201

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A Sample Relational Database

customer_id	customer_name	customer_street	customer_city
192-83-7465	Johnson	12 Alma St.	Palo Alto
677-89-9011	Hayes	3 Main St.	Harrison
182-73-6091	Turner	123 Putnam Ave.	Stanford
321-12-3123	Jones	100 Main St.	Harrison
336-66-9999	Lindsay	175 Park Ave.	Pittsfield
019-28-3746	Smith	72 North St.	Bay

(a) The customer table

account_number	balance
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

customer_id	account_number
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

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SQL

- SQL: widely used non-procedural language
 - Example: Find the name of the customer with customer-id 192-83-7465


```
select customer.customer_name
from customer
where customer.customer_id = '192-83-7465'
```
 - Example: Find the balances of all accounts held by the customer with customer-id 192-83-7465


```
select account.balance
from depositor, account
where depositor.customer_id = '192-83-7465' and
depositor.account_number = account.account_number
```
- 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

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Database Design

The process of designing the general structure of the database:

- Logical Design – Deciding on the database schema. Database design requires that we find a “good” collection of relation schemas.
 - Business decision – What attributes should we record in the database?
 - Computer Science decision – What relation schemas should we have and how should the attributes be distributed among the various relation schemas?
- Physical Design – Deciding on the physical layout of the database

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The Entity-Relationship Model

- Models 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: an association among several entities
- Represented diagrammatically by an *entity-relationship diagram*:

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Object-Relational Data Models

- Extend the relational data model by including object orientation and constructs to deal with added data types.
- 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 with existing relational languages.

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XML: Extensible Markup Language

- Defined by the WWW Consortium (W3C)
- 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 all new generation data interchange formats.
- A wide variety of tools is available for parsing, browsing and querying XML documents/data

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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 to the following tasks:
 - Interaction with the file manager
 - Efficient storing, retrieving and updating of data
- Issues:
 - Storage access
 - File organization
 - Indexing and hashing

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Query Processing

1. Parsing and translation
2. Optimization
3. Evaluation

```

    graph TD
      query[query] --> parser[parser and translator]
      parser --> ra[relational algebra expression]
      ra --> optimizer{optimizer}
      optimizer --> plan[execution plan]
      plan --> engine[evaluation engine]
      engine --> output[query output]
      data[(data)] --> engine
      stats[(statistics about data)] --> engine
  
```

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Query Processing (Cont.)

- Alternative ways of evaluating a given query
 - Equivalent expressions
 - Different algorithms for each operation
- Cost difference between a good and a bad way of evaluating a query can be enormous
- Need to estimate the cost of operations
 - Depends critically on statistical information about relations which the database must maintain
 - Need to estimate statistics for intermediate results to compute cost of complex expressions

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Transaction Management

- A **transaction** is a collection of operations that performs a single logical function in a database application
- **Transaction-management component** ensures 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** controls the interaction among the concurrent transactions, to ensure the consistency of the database.

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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
- Parallel (multi-processor)
- Distributed

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Database Users

Users are differentiated by the way they expect to interact with the system

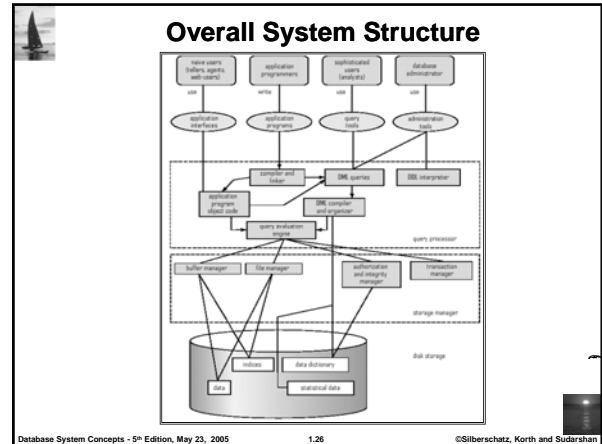
- **Application programmers** – interact with system through DML calls
- **Sophisticated users** – form requests in a database query language
- **Specialized users** – write specialized database applications that do not fit into the traditional data processing framework
- **Naïve users** – invoke one of the permanent application programs that have been written previously
 - Examples, people accessing database over the web, bank tellers, clerical staff

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Database Administrator

- Coordinates all the activities of the database system; the database administrator has a good understanding of the enterprise's information resources and needs.
- Database administrator's duties include:
 - Schema definition
 - Storage structure and access method definition
 - Schema and physical organization modification
 - Granting user authority to access the database
 - Specifying integrity constraints
 - Acting as liaison with users
 - Monitoring performance and responding 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
 - Ted Codd defines the relational data model
 - Would win 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

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History (cont.)

- 1980s:
 - Research 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:
 - XML and XQuery standards
 - Automated database administration

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End of Chapter 1

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