Databases

Jörg Endrullis

VU University Amsterdam

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- a specific semantics
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- enable durability and recovery from failure
- control access to the data by many users in parallel
  - without unexpected interactions among users (**isolation**)
  - actions on the data should never be partial (**atomicity**)

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- logical structure limited to directories
- no efficient access
  - searching through a large file can take hours
- no or limited protection from data loss
- no access control for parallel manipulation of data

Motivation for Database Management Systems

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- **data independence**
  - logical view on the data independent of physical storage
  - user interacts with a simple view on the data
  - behind the scenes (invisible for the user) are complex storage structures that allow rapid access and manipulation

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  - different views on the same database
    - for different users or different applications
    - hiding parts of the data for privacy or security

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  - different views on the same database
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    - hiding parts of the data for privacy or security
- high-level **declarative query languages**
  - query tells what you want, independent of storage structure
  - efficient data access (automatic query optimisation)

Relational Model

Schema: structure of the database = relations + constraints

Example Schema

- customer(id, name, street, city)
  Primary key constraint on id
- account(depositor $\rightarrow$ customer, accountnr)
  Foreign key constraint on depositor

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customer

<u>id</u>	name	street	city
192837465	Johnson	12 Alma	Palo Alto
019283746	Smith	4 North	Rye

account

depositor	<u>accountnr</u>
19283465	101343
019283746	215569

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Various types of constraints:

- data types, constrained data types (domains), nullability
- columns constraints (e.g. unique, counter, time stamp,...)
- check constraints (logical expression for domain integrity) (e.g. `age >= 18 AND age <= 150`)

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Example Relational Database Instance

customer			
id	name	street	city
192837465	Johnson	12 Alma	Palo Alto
019283746	Smith	4 North	Rye
192837465	Johnson	3 Alma	Palo Alto
321123123	Jones	34 Main	Harisson
019283746	Smith	7 South	Rye

account	
depositor	accountnr
19283465	101343
019283746	215569
192837465	201541
321123123	217343
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- tuple record (row)

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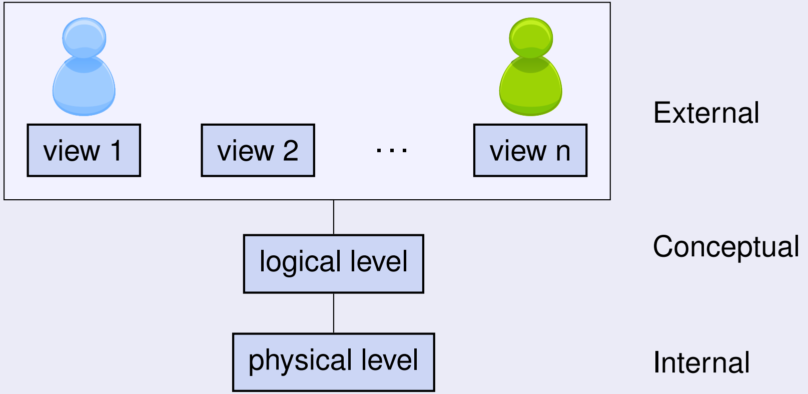
In the **pure relational model**, a table is a **set** of tuples:

- has no duplicate tuples (rows)
- no order on the tuples

View of Data

- Different applications might use different views
- Data is stored only once at the physical level
    - good for consistency

ANSI SPARC Architecture: 3 levels



ANSI SPARC Architecture: 3 levels

- **Physical level:** how a record (e.g. information about some product) is stored
  - disk pages, index structures, byte layout, record order
- **Logical level:** also called ‘conceptual schema’
  - describes data stored in the database, and
  - relations among the data

SQL DDL (Data Definition Language)

```
CREATE TABLE SOLVED (STUDENT VARCHAR(40),
                     HOMEWORK NUMERIC(2),
                     POINTS NUMERIC(2));

CREATE VIEW SOLVED_HOMEWORK AS
    SELECT STUDENT, HOMEWORK FROM SOLVED;
```

- **View level:**
  - application programs hide details of data types
  - hide information (e.g. exam grade) for privacy or security

Data Independence

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Physical data independence: ability to modify the physical schema without changing the logical schema

- e.g. a change in workload might cause the need for
  - different indexing structures
  - different database engine
  - distributing the database on multiple machines
  - …

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Kowalski

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- explicit control
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- implicit logic

Declarative/non-procedural languages:

- implicit control
- explicit logic
- e.g. logic programming (Prolog), functional programming (Haskell), markup languages (HTML), ...

SQL = Structure Query Language

SQL is a declarative data manipulation language. The user describes conditions the requested data is required to fulfil.

SQL Query

```
SELECT POINTS
FROM SOLVED
WHERE STUDENT = 'Ann Smith'
  AND HOMEWORK = 3
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  - decides how to execute the query as fast as possible
- (usually) users do not need to think about efficiency

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  - relational model
    - e.g. SQL table and constraint definitions

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  - meta language for describing
    - data
    - data relationships
    - data semantics
    - data constraints

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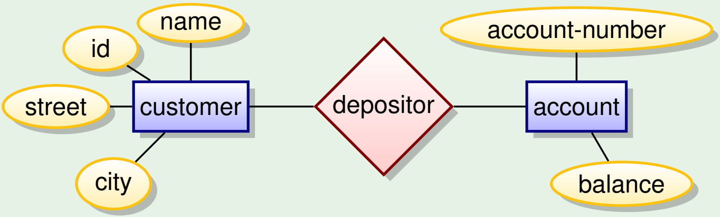
Other models:

- object-oriented models (e.g. ODL)
- semi-structured data models (DTD, XML Schema)
- …

Entity Relationship Model

Entity relationship model

- entities = objects
  - e.g. customers, accounts, bank branches
- relationship between entities
  - e.g. account 101343 is held by customer Johnson
  - **relationship set descriptor** associates customers with accounts



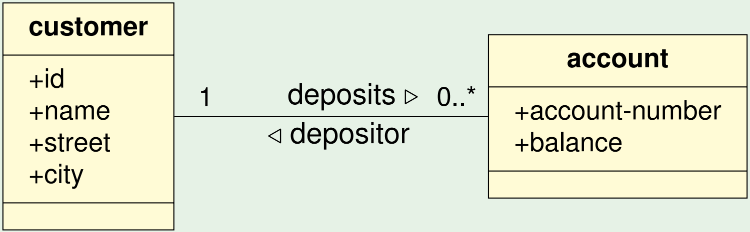
- widely used for database design
- usually converted to the relational model

UML Class Diagram

UML class diagrams

- frequently used in database design
- similar to E/R diagrams
  (**Entities/Relationships** $\Longrightarrow$ **Classes/Associations**)

Example Schema as UML Class diagram



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- **Durability:** once a transaction is committed successfully, the modified data is persistent, regardless of disk crashes

Symmary

Why Database Management Systems?

- **data independence**
  - logical view on the data independent of physical storage
- **avoidance of duplication**
  - different views on the same database
- high-level **declarative query languages** (what, not how)
  - efficient data access, automatic query optimisation
- **data models** & **data integrity (consistency)**
- multiple users, **concurrent access**
  - transactions with ACID properties
- **persistent storage**, **safety** and **high availability**
  - safety against failure (backup/restore)
- **scalability** (data could by much larger than main memory)
  - indexing, scalable algorithms
- **security**