Politecnico di Torino

Introduction to databases

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Introduction to databases

- Information management
- Databases
- Data model
- Design of a database
- Data independence
- Data access
- Advantages and disadvantages of a DBMS

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Information management

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Information management

- Information is recorded and exchanged in different forms
- Over time, different methods and formats to organize and codify information have been introduced

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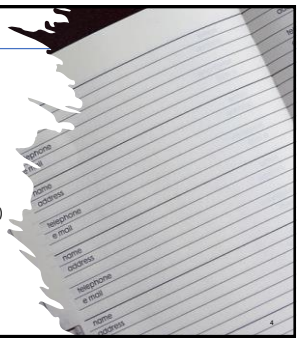
Computer systems

- In computer systems information is represented by means of data
  - the data are raw symbols which have to be interpreted and correlated to provide information
- Example
  - data: "Laura Smith" and 424242
  - Information: result of looking up a telephone number in your personal telephone directory (e.g., list of contacts)



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Data characteristics

Data are far more stable over time than the processes that manage them

Example:

- there have been virtually no variations in the data structure of bank applications for decades
- the procedures that manage the data vary from year to year

Data are an important resource for the organization that manages them

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Databases

Introduction to databases

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Database

- General definition
  - a database is a collection of data that represents information of interest for a computer system
- "Technical" definition
  - A database is a collection of data managed by a DBMS (Database Management System)

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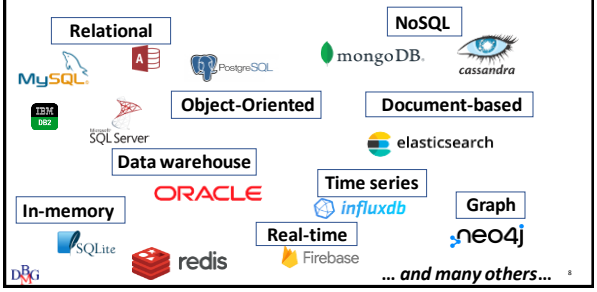
Types of databases - DBMS



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Data Base Management System - DBMS

- A DBMS (Data Base Management System) is a software system able to manage collections of data that are
  - large
  - shared
  - persistent

  ensuring their reliability and privacy

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DBMS characteristics

- Far greater dimension than the central memory available
  - data management in secondary memory
- Data sharing between applications and user: a database is an *integrated* resource, shared by several company sectors
  - reduction of data redundancy
  - reduction of data inconsistency
  - competing access control mechanism

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DBMS characteristics

Data persistence	Data reliability in the case of hardware and software malfunction/failure	Data privacy	Efficiency	Efficacy
lifetime not limited to the exection of softwares that use them	backup and recovery functionality	authorization mechanisms to grant rights to users	capability to carry out operations using a set of resources (time and space) acceptable for users adequately sized computer system	capability to make user activities productive

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DBMS or file system?

- "Simplified" approach to data: data stored in a persistent mode in the mass/secondary memory inside a file
  - it is possible to memorize and look for data
  - simple access mechanisms (sequential reading)
  - simple sharing mechanisms (read only sharing, blocking write access rights)
- DBMS extends the functionalities of the file system, providing more integrated services

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Data model

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Data model

- A data model is a set of concepts utilized for organizing data of interest and describing its structure in a way that is understood by a computer
  - Elementary data types (integer, character, ...)
  - Structuring mechanism for defining more complex structures (record builder, array, ...)

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Types of data models

- Relational model
  - Most widespread data model
  - Data are organized into sets of homogeneous (fixed structure) records and represented as tables
- Before the relational model, other models closer to the physical structures of storing were used
  - Hierarchical model, network model
- Since the relational model
  - Object model, XML, database NOSQL, ...

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Relational model

Teacher

Name	Department	Phone
Green	Computer Engineering	123456
White	Telecommunications	636363
Black	Computer Engineering	414243

Courses

Code	Name	Teacher
M2170	Information Systems	Green
M4880	Computer Networks	White
F0410	Databases	Black

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Schema and instances

- In a database we define:
  - the *schema*, which describes the structure of the data
    - It is practically unvarying over time
    - It is represented by the header of each table (table name and column names)

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SCHEMA

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SCHEMA

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Schema and instances

- In a database we define:
  - the *instance*, composed of the content of each table, i.e. of the actual data values which are
    - Variable over time, also very rapidly
    - Represented by the rows in the tables

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INSTANCE

Courses

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F0410	Databases	Black

INSTANCE

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Example of other data models: Database NOSQL

- A database is a set of collections
- Each collection contains a set of documents
- Each document is described as a list of key-value fields and each field can contain data of any type
- Documents in the same collection can be heterogeneous
- Since the data representation is schema-less, it is not necessary to define in advance the document schema and documents in the same collection can be characterized by different fields

Relational database	NOSQL database
Tables	Collection
Row	Document
Column	Field

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Example of data of a document

- Relationships between documents are inefficient and lead to denormalization
  - Document reference (ID), without native join

```
{
  _id: <ObjectId1>,
  username: "123xyz",
  contact: {
             phone: "123-456-7890",
             email: "xyz@example.com"
           },
  access: {
             level: 5,
             group: "dev"
           }
}
```

Embedded sub-document

Embedded sub-document

Source: https://www.mongodb.com/docs/manual/core/data-model-design/

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Types of model

Conceptual model

- It is possible to represent data indipendently from the logical model
  - describes real world concepts
  - used in the designing phase
- Example: entity-relationship model

Logical model

- Describes the data structure in the DBMS
  - used by the programmers accessing the data
  - Indipendent from the physical structure
- Example: relational model

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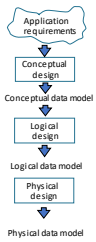
Design of a database

Represent the informal requirements of an application in terms of a conceptual schema that refers to a conceptual data model

Translation of the conceptual schema previously defined into the database logical schema that refers to a logical data model

The logical schema is completed by the details of the physical implementation (file organization and indices) on a given DBMS. The product is called physical schema and refers to a physical data model



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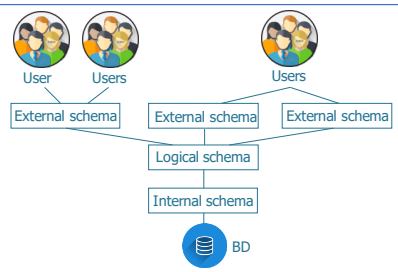
Level of abstraction of a DBMS



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Standard three-level ANSI/SPARC architecture for DBMS

- Logical schema
  - Description of the database using the logical model of the DBMS
- Internal schema
  - Representation of the logical schema on the physical storage structure
- External schema
  - Description of parts of the database, called "views", which reflect the point of view of particular users
  - Defined on the logical model

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Data independence

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Data independence

- Data independence guarantees that users and application software which utilize a database can ignore the designing details used in the construction of the database
- It is a consequence of dividing the design process at different abstraction levels
- Levels of data independence:
  - Physical independence
  - Logical independence

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Data independence

- Physical independence
  - Enables interaction with the DBMS independently from the physical structure of the data
  - Access to a (logical or external level) relationship always takes place in the same way, independently of how data is actually stored
  - It is possible to change the way the data is physically stored without affecting or changing the software applications using them

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Data independence

- Logical independence
  - Enables interaction with the external level independently of the logical level
  - It is possible to change the logical level maintaining the external structures unaltered (as long as the correspondences are unaltered)
  - It is possible to add new views or alter existing views without changing the logical schema

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Data access

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Data access languages

- User-friendly interfaces that enable specific queries without using a textual language
- Interactive languages (es., SQL, DSL)
- Command similar to interactive commands introduced into traditional programming (C, C++, COBOL, Java, Python, …), so-called host languages
- ORM (Object-Relational Mapping): mapping objects into programming languages with database tables/documents
- Commands similar to interactive commands introduced into ad hoc programming languages, often with specific functionalities (generation of graphs, printed documents, complex pages, etc.)

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Data access languages

- Languages are divided into two categories
  - *Data Definition Languages* (DDL) used to define the logical, external and physical schemas, and access authorizations
  - *Data Manipulation Languages* (DML) used for querying and updating database instances

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Users

- **Database administrator**: in charge of (centralized) control and management of the databse
  - guarantees sufficient performance
  - ensures system reliability
  - manages authorizations and access to data
- **Designers and programmers**: they define and realize
  - the structure of the database
  - the programmes accesing the database
- **Users**: they use the database for their activities
  - end users: they use transactions, i.e. programmes that carry out predefined activities
  - casual users: they formulate queries (or updates) which are not predefined by the interactive access languages of the database

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Transactions

- Applications that carry out frequent predefined activities
- Example
  - Flight bookings
  - Bank transfers
  - E-commerce purchase
- Generally realized by introducing SQL into a host language

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Advantages and disadvantages of DBSM

Introduction to databases

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DBMS advantages

- Data as a common resource of the whole organization
  - Reduction of redundancies and inconsistencies
- Unified and precise data model of facts of interest to the organization
- Possible centralized control of data
  - standardization, economies of scale
- Data independence

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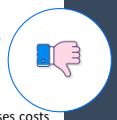
DBMS disadvantages

- These are expensive, complex products that require
  - direct investment
    - purchasing the product
  - indirect investments
    - purchasing the necessary hardware and software resources
    - adapting existing applications
    - training personnel
- They provide a set of services in an integrated form
  - it is not possible to separate out unused services, which increases costs and may reduce performance



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