Databases

Introduction

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Studying Method

- Self study, focus on the fundamental concepts and refer to personal experiences
- Doing exercises
- Developing a project or attending the exercises during the lectures, using a proper tool (such as *DB2, SQLServer, Oracle, PostgreSQL, MySQL, MS Access, …*)

Database

- An organized set of data that supports on carrying out specific activities (within an institution, an enterprise, an office, a human)

Point of View

- Methodological
- Technological

Contents

- Models for organizing data
- Languages for using data
- Systems for handling data
- Database design methodologies

Information System

- A component of an institution that handles the interesting pieces of information (e.g., in order to pursue the corporate goals)
- Each institution has its own information system, that could be not explicitly identifiable within its organization
- The information system supports other “subsystems”. For this very reason it should be studied inside its operative context

Handling the Information

- Gathering, acquisition
- Storing, preservation
- Elaboration, transformation, production
- Distribution, communication, exchange

Information System and Automation

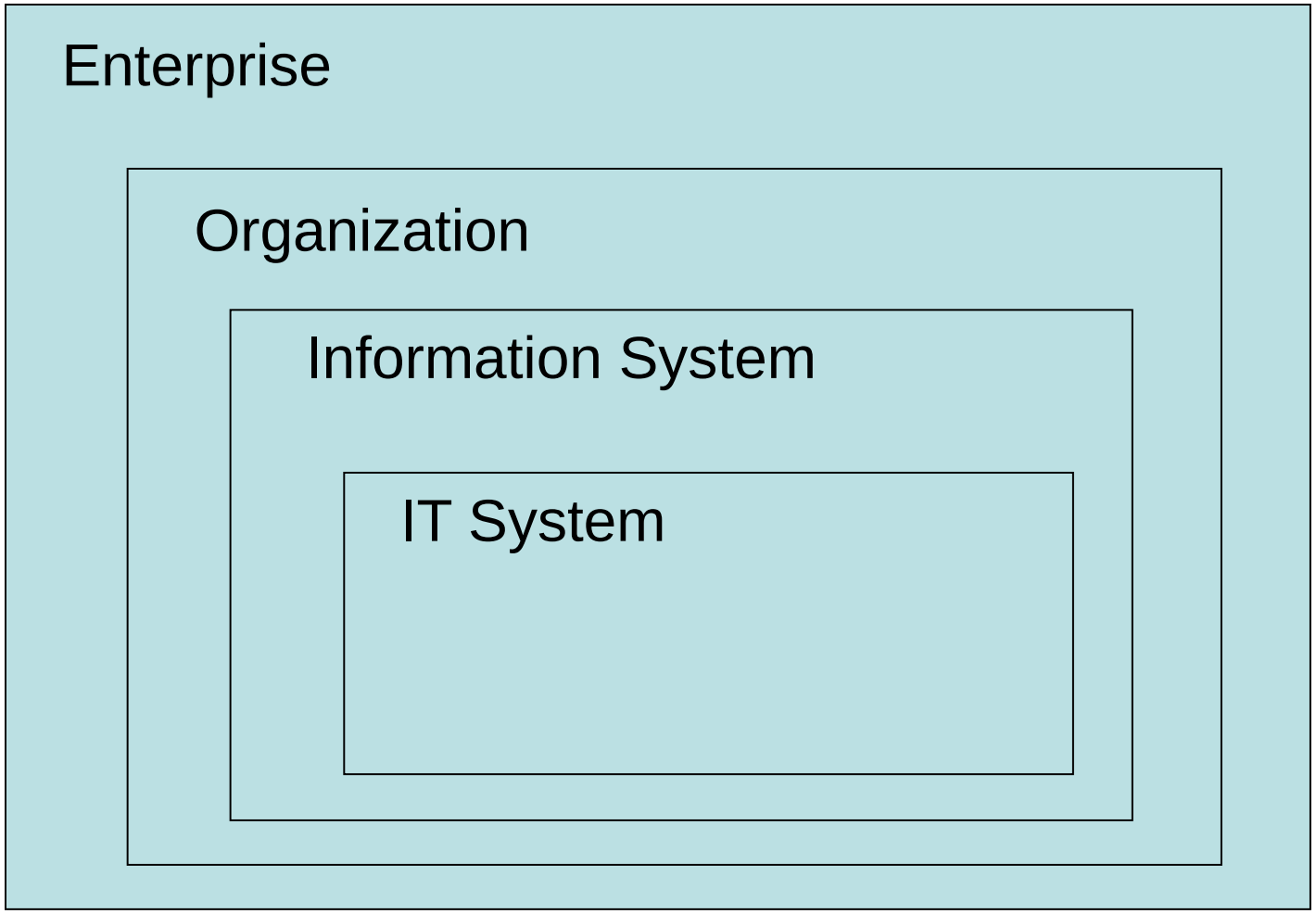
- The idea of “information system” is independent from any computer automation:
  - Some organizations have the only mission of handling data (e.g., demographic recordings and banking services) and they existed for centuries

IT System (1)

- One of the automated parts of the Information System:

  It’s the information system component that handle information using computer technologies

IT System (2)



Handling the Information

- Different human activities could represent the pieces of information differently:
  - informal ideas
  - natural language (written or word of mouth, formal or conversational, in different languages...)
  - drawings, plottings, diagrams
  - numbers and codes
- Such information has different storage media:
  - Human brain, paper, electronic devices

Information and Data (1)

- Within (e.g.) IT Systems, the **information** is roughly expressed as **data**

Information and Data (2)

Information: facts provided or learned about something or someone

Data: pieces of information. A fixed starting point of a operation

[Oxford Dictionary]

Information and Data (3)

Mon-Fri

Saturday

Holiday

- What does those numbers mean?
- Road signs in Finland; they are hours
- But what is the difference between them?
- The datum is useless without its “interpretation”

Handling Information

- Data is the result of the process of organizing, coding and storing of information
- For instance, within demographic registries when referring to citizens
  - Wordy descriptions
  - Name and Surname
  - Personal pieces of information
  - Personal Tax Code

Why Data?

- It is difficult to precisely represent very rich pieces of information and knowledge
- Data are a strategic resource, because they are more stable than other representation (business processes, technologies, human roles):
  - e.g., data in banks and demographic registries

Databases

(generical meaning)

- An organized set of data that supports on carrying out specific activities of an entity (an institution, an enterprise, an office, a human)

(specific meaning)

- Set of data handled by a DBMS

DataBase Management System (DBMS)

- Any system handling data collections that are:
  - big
  - persistent
  - shared
- While ensuring:
  - privacy
  - reliability
  - efficiency
  - effectiveness

DBMS

- Software as a product and as a service (complex) available on the market:
  - DB2
  - Oracle
  - SQLServer
  - MySQL
  - PostgreSQL
  - Access
  - BigQuery
  - SQLite

Databases are ... Big

- Their size are (by far) greater than the computing systems' main memory
- Only the devices' physical limit is considered
- Some example of big sizes
  - 1-5 Terabyte (transactional data)
  - 30-50 Terabyte (decision data)
  - 500-800 Terabyte (scientific data)
  - 100 billions of records

Data bases are ... Persistent

- Their lifetime is independent from the lifetime of the computer processes using such data

Databases are … Shared

- Every (big) corporation is sliced in different areas, e.g., it could carry out different activities
- Each area/activity has a information (sub)system (that is not necessarily detached from the central one)

Problems

- Redundancy …
  - same data appears many times
- … could cause inconsistency:
  - different descriptions could not match

Databases are … Shared

- A database is an integrated and shared resource among the software applications
- As a consequence
  - Different activities build up on shared data:
    - requires permission mechanisms
  - More users access shared data:
    - requires concurrency checks

Databases preserve ... Privacy

- We could implement permission mechanisms such as:
  - "*User A is allowed to read all the data and to edit data X*"
  - "*User B is allowed to read data X and to edit data Y*"

Databases preserve ... Reliability

- Reliability (w.r.t. databases):
  - are tolerant w.r.t both hardware and software failures
- A database is a precious resource and, consequently, should be preserved for a long time to come
- Crucial technique:
  - Transactions handling

Transaction

- A set of non-detachable operations (*atomic*) …
- that are correct even on a concurrent system …
- … with final effects

Transactions are … Atomic

- A sequence of related operations:
  - "*Move the money from the bank account A to B: either the withdraw is performed on A and transferred to B or no operation is carried out*"
- … either is performed as a whole, or is not performed at all:
  - "*either the withdraw is performed on A and transferred to B or no operation is carried out*"

Transactions are … Concurrent

- Concurrent transactions must be coherent
  - *If two different checks are issued on a same bank account and are cashed contemporarily … you must not miss one of them*
  - *If two different agencies want to book the same (available) sit on a train … you must not book it twice*

The Effect of Transactions are Permanent

- The commit of a transaction requires that the final result should be logged and tracked, even in a concurrent context or when failures occur

Databases must be … Efficient

- They try to use profitably the memory (*primary* and *secondary*) and time (of *running* and *response*) resources
- Since DBMS provide many operations, they could be implemented inefficiently. For this reason there are huge investments and competition
- Efficiency is also a result of software quality

Databases must be … Effective

- Databases try to improve the activities of their users, by providing powerful and flexible functionalities:
  - a frequent topic of the lectures is how DBMSs pursue effectiveness

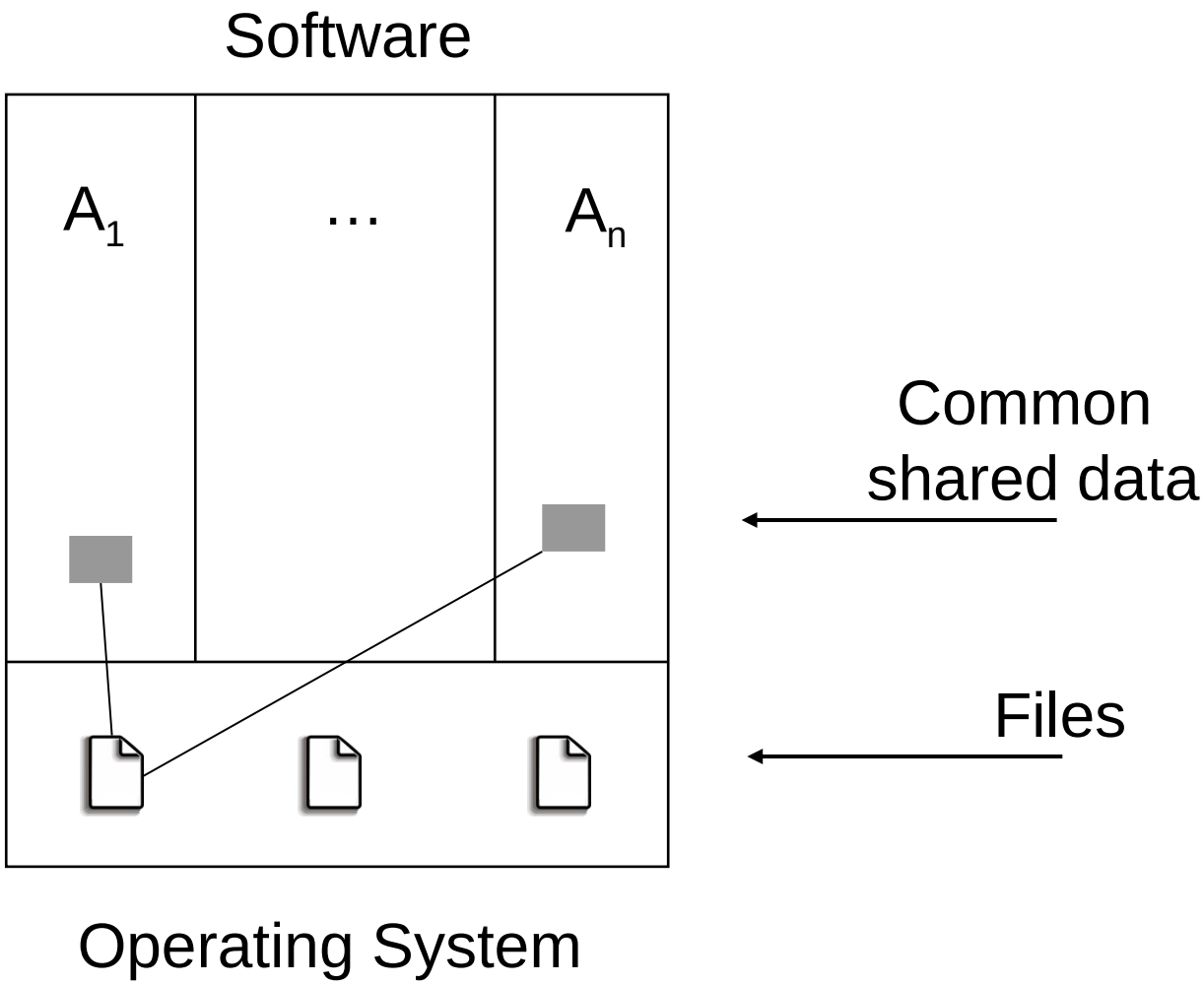
DBMS vs File System

- Big collections of data could be also handled by simpler systems, such as standard Operating Systems' file system
- File systems provide a coarse grained access to data: "all or nothing"
- DBMSs extend the file system's features, by providing more services and in a more integrated fashion

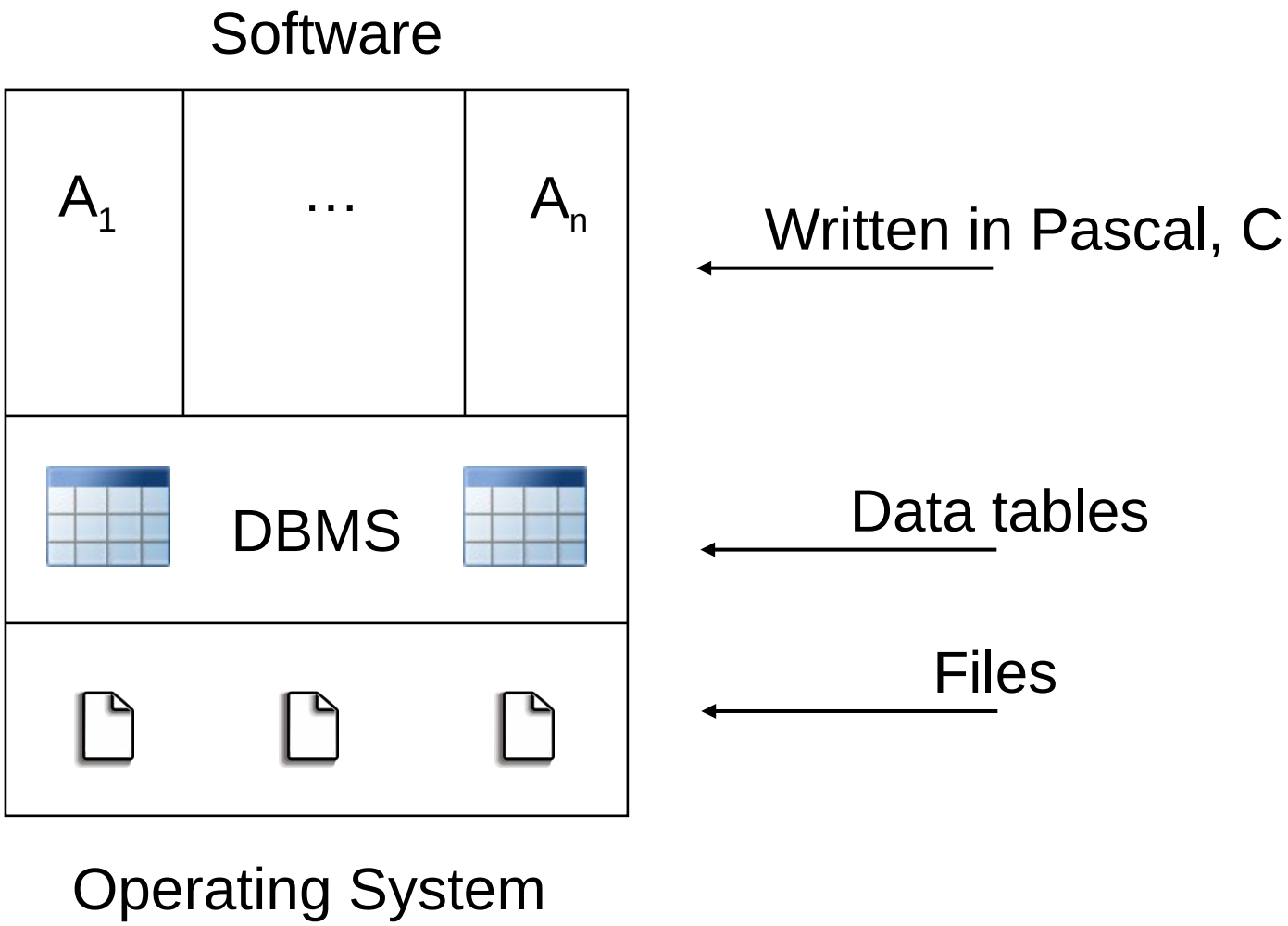
Let’s see how Data Management

evolved through time

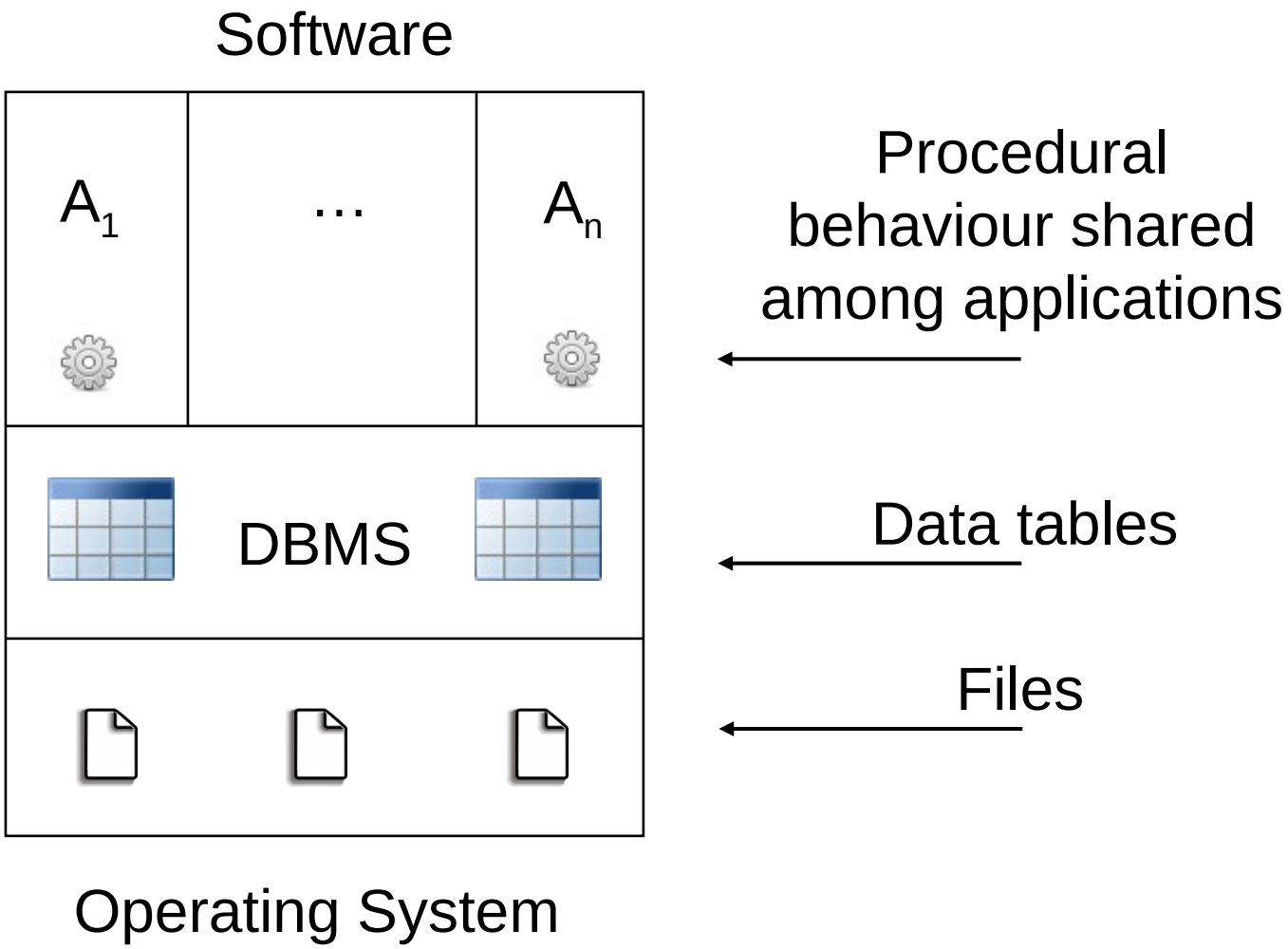
The 70s: no DBMS



The 80s: First DBMSs



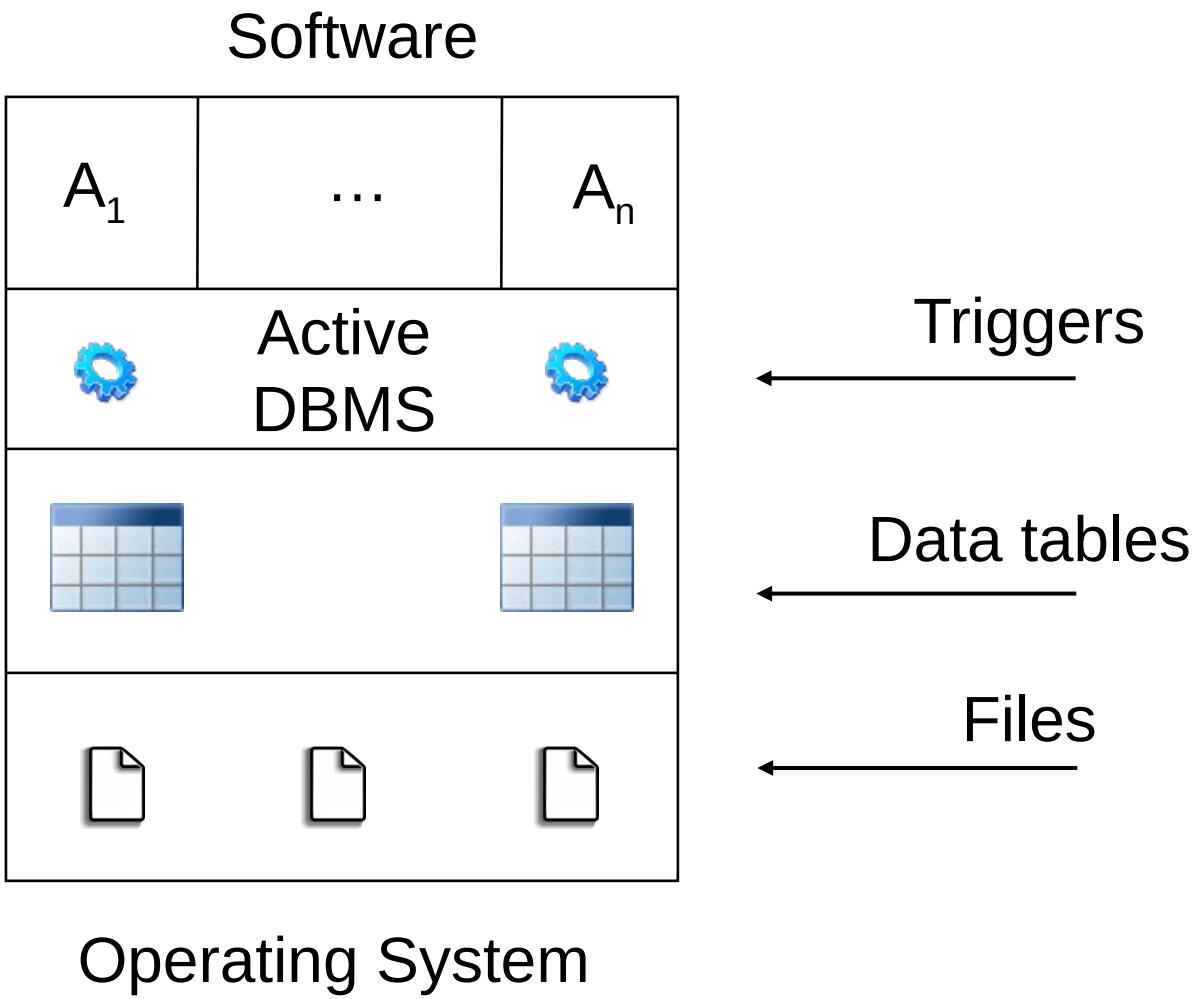
The 90s: the Procedural Behaviour



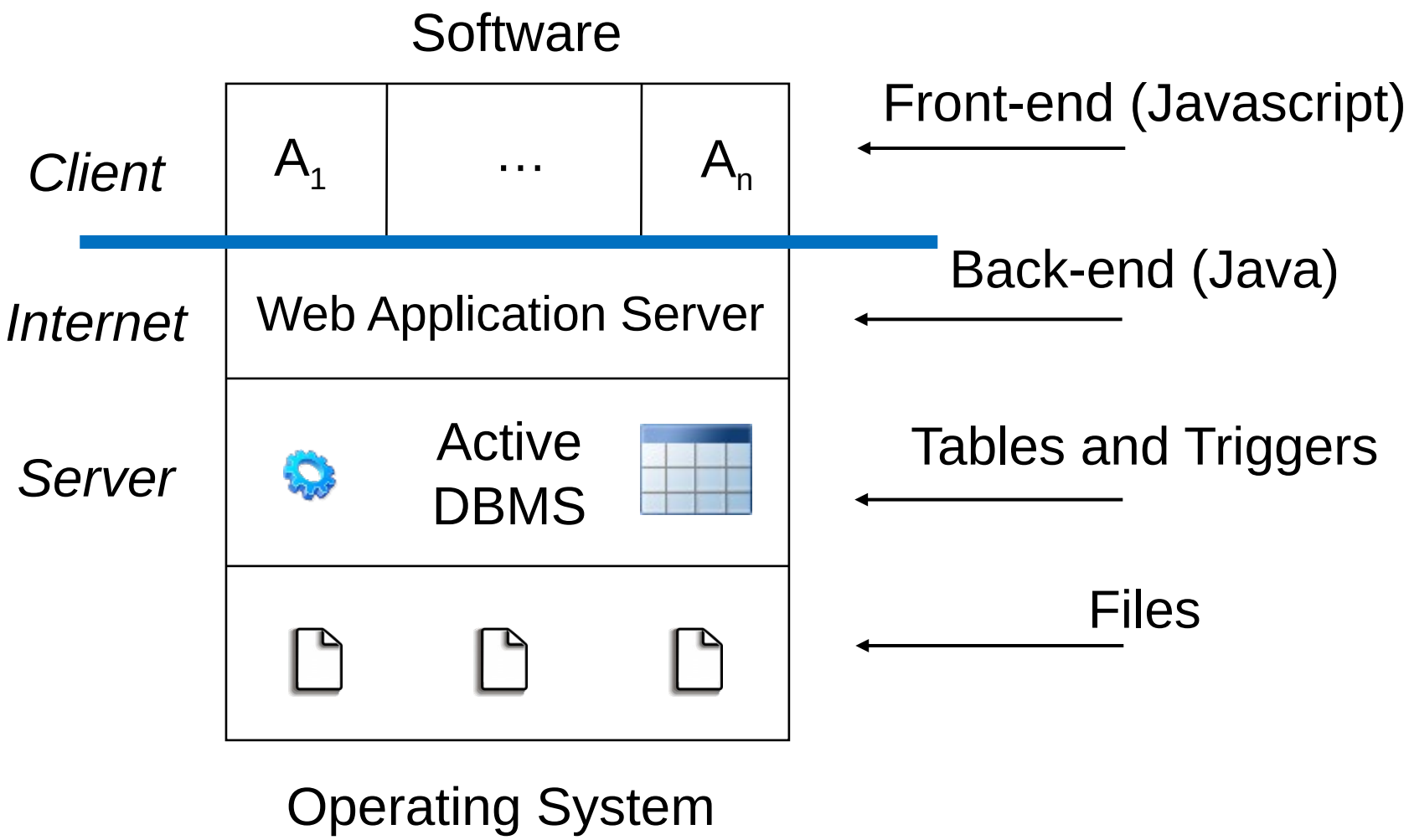
Advances in DBMSs: Stored Procedures

- Stored procedures have been introduced to share the common procedural behaviours between different software
- Stored procedures are not standardized and are affected by the problem of impedance mismatch (we'll see later) with the language used to express such procedures
- As a result specific rules (*triggers*) have been introduced to model the procedural behaviour shared among different software and are handled by the DBMS itself

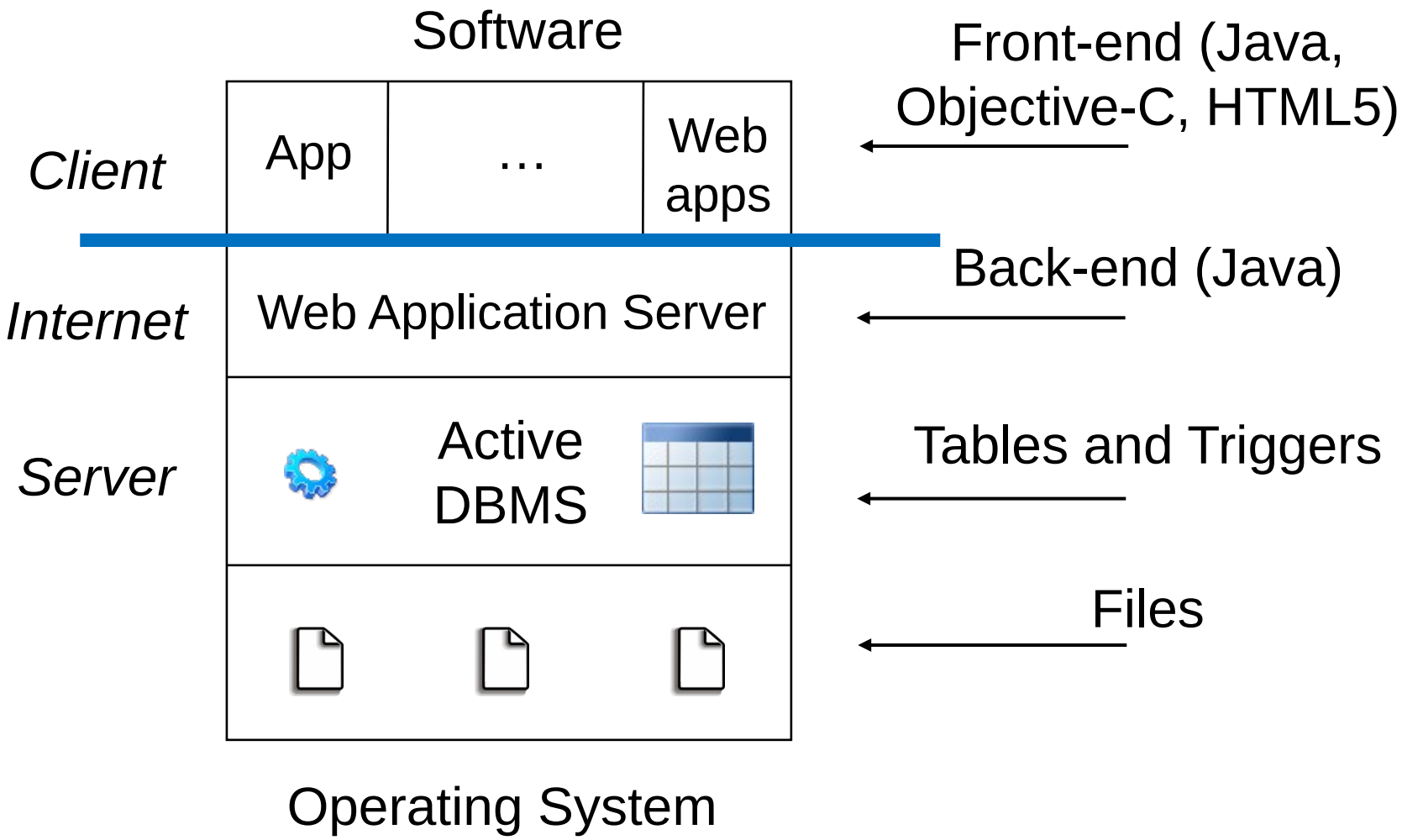
The 90s: Active DBMS



Advance in the 2000s



The 2010s: Mobile Apps



Describing Data

- Each software (that does not rely on a DBMS) contains an internal description of the file structure that is going to be processed. As a drawback, multiple software could have multiple data description: this situation generates inconsistency within data representations
- In DBMSs, a portion of the database (the catalogue or dictionary) contains a centralized description of the data: the same description is shared among all the software applications

Describing Data in DBMS

- Data are described at different levels of abstraction
  - Data are not dependent from their physical representation:
    - Programs use a high level representation, independent from the data representations at a lower level. As a consequence, a change in the lower level does not require changes in the programs.
  - This is more precisely obtained through the **data model** concept

Data Model

- A set of constructs that are used to organize and describe the behaviour of the data
- Crucial component: providing structure to data (via type constructor)
- The data model provides some default data type constructors, as it usually happens on current programming languages
- The relational model provides the constructor relation, allowing to define a set of homogeneous records

Organizing Data in a Database

SCHEDULING			
Lectures	Lecturer	Room	Time
Calculus I	Luigi Neri	N1	8:00
Databases	Pier Rossi	N2	9:45
Chemistry	Nicola Mori	N1	9:45
Physics I	Mario Bruni	N1	11:45
Physics II	Mario Bruni	N3	9:45
IT Systems	Pier Rossi	N3	8:00

Organizing Data in DBMS

A **schema**

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Some **instances**

Schema and Instances

- In every database there exist:
  - the **schema**: it is time invariant and describes the data structure (intentional aspect)
    - e.g., tables' headers
  - the **instance**: the actual values that could rapidly change (extensional aspect)
    - e.g., the tables' body

Two Different Aspects

- **Conceptual** Modelling
- **Logical** Models

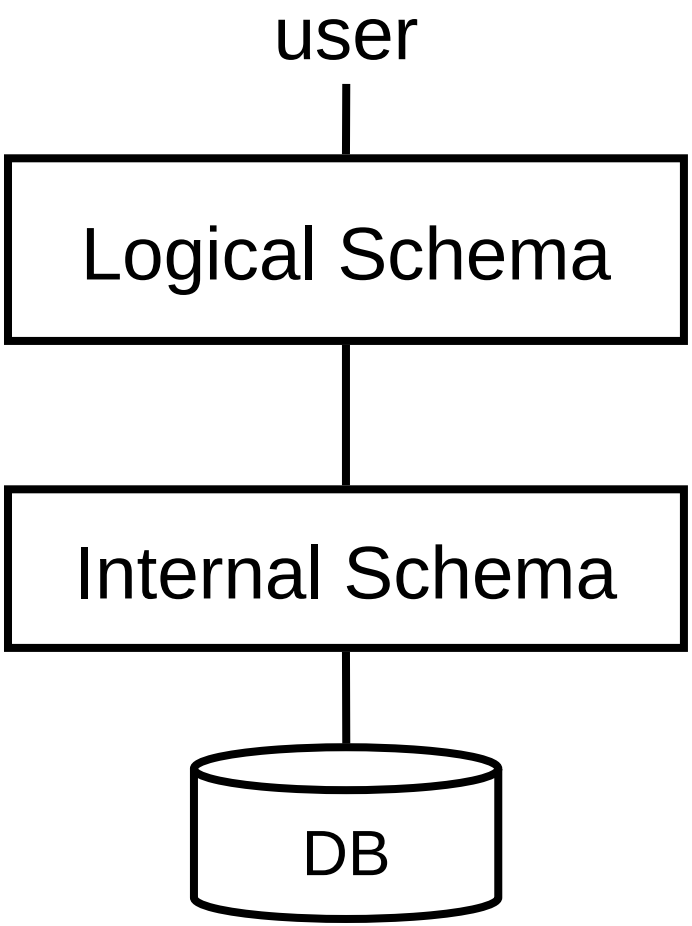
Conceptual Modelling

- They represent data independently from each specific system
  - they describe concepts from the real world
  - they are used in the preparatory phase of a project
- The most diffused data model language is Entity-Relationship

Logical Models

- DBMS use such models to store and organize the data
  - used by software at a higher level
  - independent from the physical representation
- For instance, relational, lattice, hierarchical, object, XML

Simplified Architecture of a DBMS



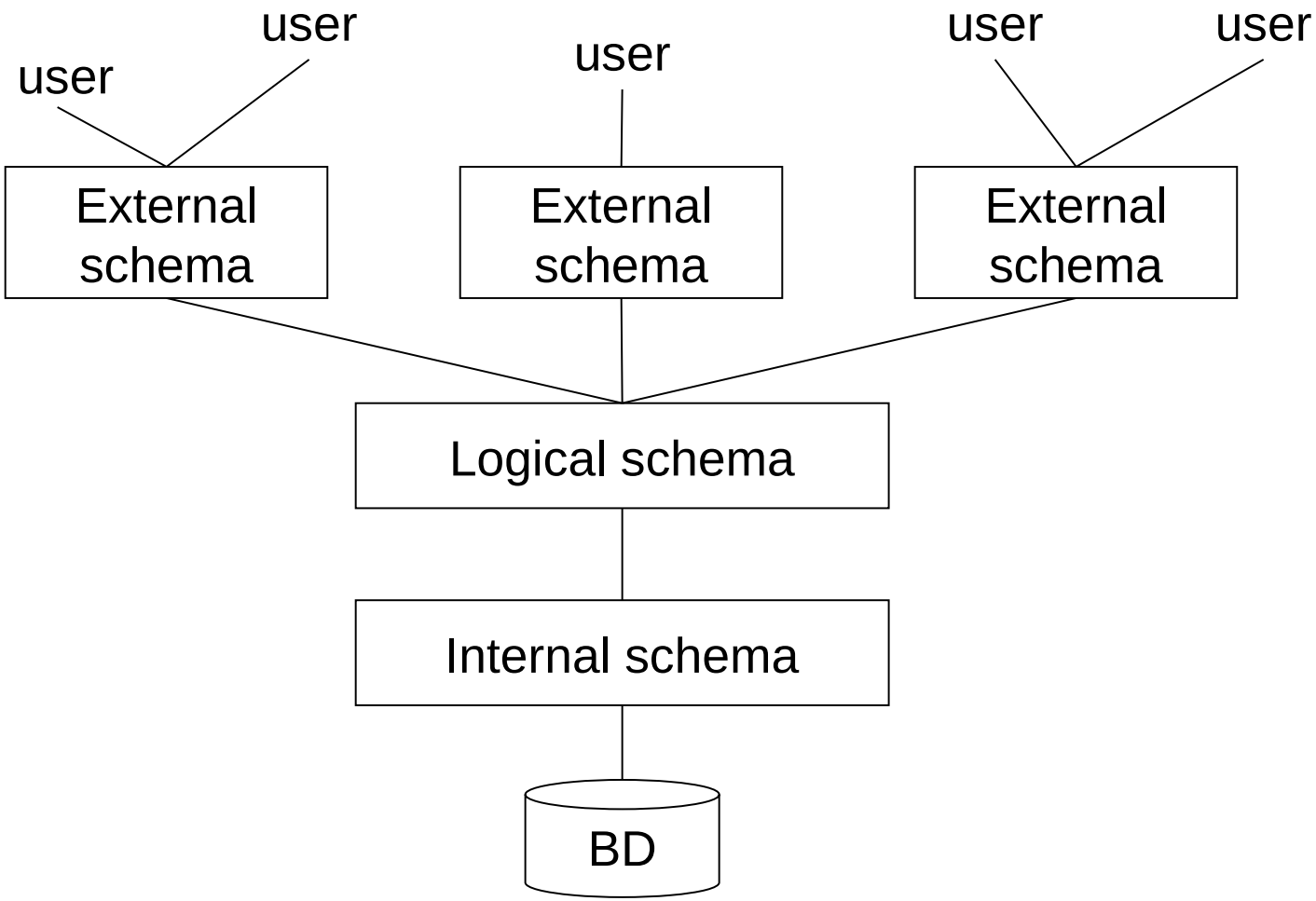
Simplified Architecture of a DBMS: Schema

- **Logical schema**: describes the structure of the database through the logical data model (e.g., the table's structure)
- **Internal (or physical) schema**: represents the logical schema at the storage level using specific *raw* data structures (such as files, records and data pointers)

Data Independence (1)

- The data representation at the logical level is independent from the one at the physical level:
  - a table is handled “as it is” independently from its underlying representation (that could even vary over time)
- For this very reason in this course we will see only the logical level and not the internal one

Standard Three-tiered ANSI/SPARC Architecture



ANSI/SPARC Architecture: Schema

- An **internal schema** represents the conceptual level at the storage level using specific *raw* data structures (such as files, records and data pointers)
- A **logical schema** describes the structure of the database through the “main” logical data model
- An **external schema** describes part of the database in a logical model (partial “views”, derived tables, even from different models)

Views

LECTURES

Lecture	Lecturer	Room
Databases	Rossi	DS3
Systems	Neri	N3
Networks	Bruni	N3
Controls	Bruni	G

ROOMS

Name	Building	Floor
DS1	OMI	Ground
N3	OMI	Ground
G	A2	First

LECTURESROOMS

Lecture	Room	Building	Floor
Systems	N3	OMI	Ground
Networks	N3	OMI	Ground
Controls	G	A2	First

Data Independence (2)

- Is the consequence of having different layers
- The data access is provided by the external level (that could coincide with the logical one)
- Two types of independence:
  - Physical data independence
  - Logical data independence

Physical Data Independence

- The logical and external levels have a representation which is independent from the physical level
  - a relation is “handled” in the same way independently from its physical implementation
  - The physical implementation could undergo some changes without the need of changing the software

Logical Data Independence

- The external level is independent from the logical level
- Edits and Updates on “views” do not require any change at the logical level
- “Transparent” edits of the logical schema keep the external schema unaltered

Database Languages

- Another aspect of the database effectiveness is given by its availability through different languages and interfaces
  - “interactive” textual languages (**SQL**)
  - statements (SQL) injected in a host language (Pascal, Java, C ...)
  - statements (SQL) injected in an *ad hoc* language with other features (e.g., plottings, printing tables)
  - user friendly interfaces (with no textual interface)

SQL, an “Interactive” Language (1)

LECTURES

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ROOMS

Name	Building	Floor
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N3	OMI	Ground
G	A2	First

- “Retrieve all the lectures that are held on the ground floor"

SQL, an “Interactive” Language (2)

```
SELECT Lecture, Room, Floor
FROM Rooms, Lectures
WHERE Name = Room
        AND Floor = ‘Ground’
```

Lecture	Room	Floor
Systems	N3	Ground
Networks	N3	Ground

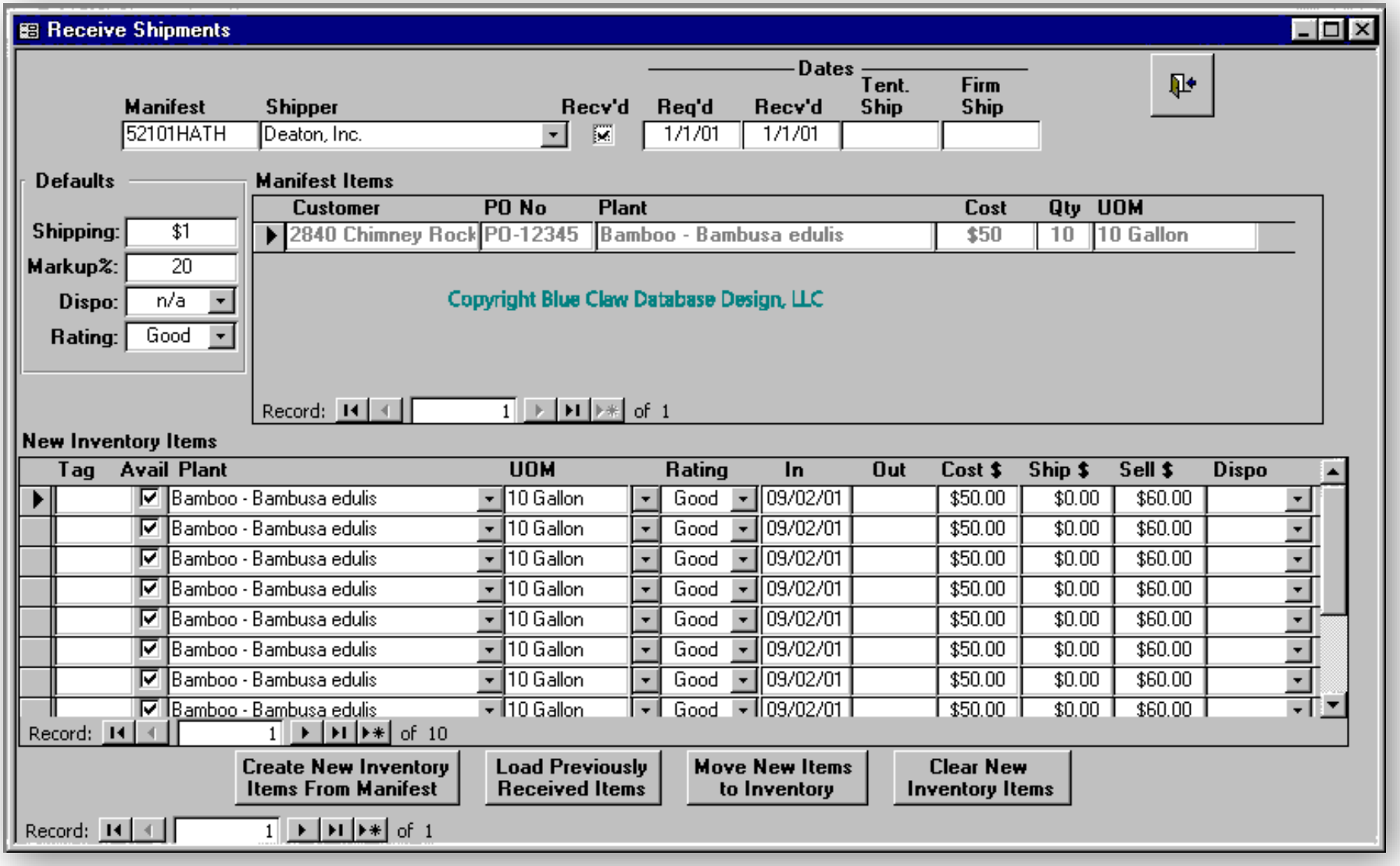
SQL Injected in a Host Language

```
write('name of the city?'); readln(citta);
EXEC SQL DECLARE P CURSOR FOR
     SELECT NAME, INCOME
     FROM PEOPLE
     WHERE CITY = :city ;
EXEC SQL OPEN P ;
EXEC SQL FETCH P INTO :name, :income ;
while SQLCODE = 0 do begin
     write('name of the person:', name, 'rise?');
     readln(rise);
     EXEC SQL UPDATE PEOPLE
          SET INCOME = INCOME + :rise
               WHERE CURRENT OF P
     EXEC SQL FETCH P INTO :name, :income
end;
EXEC SQL CLOSE CURSOR P
```

Ad Hoc SQL (Oracle PL/SQL)

```
declare Stip number;
begin
    SELECT SALARY INTO STIP FROM EMPLOYEE
    WHERE NUMBER = '575488' FOR UPDATE OF SALARY;
    if Stip > 30 then
        UPDATE EMPLOYEE SET SALARY = SALARY * 1.1
        WHERE NUMBER = '575488';
    else
        UPDATE EMPLOYEE SET SALARY = SALARY * 1.15
       WHERE NUMBER = '575488';
    end if;
    commit;
exception
    when no_data_found then
        INSERT INTO ERRORS
        VALUES('NUMBER DOES NOT EXIST',SYSDATE);
end;
```

User Friendly Interface



A Remark

Separating data from software

- data definition language (DDL)

  is used for defining the schemas (logical, external, physical) and other operations

- data manipulation language (DML)

  query and update (instances of) databases

A DDL Operation (over the schema)

```
CREATE  TABLE hours (
        course          CHAR(20),
        teacher         CHAR(20),
        room            CHAR(4),
        hour            CHAR(5)
)
```

Actors and Users

- DBMS designers and developers
- Database designers and developers
- Admins (DBA)
- Software designer and developers of end-user applications
- Users
  - final users (terminal operators): they execute predefined sets of operations (transactions)
  - end/casual users: they execute operations that are not defined *a-priori*, by using interactive languages

Database Administrator (DBA)

- A specific person or a group of people that are in charge of the controlling and handling the database in a centralized way (e.g., efficiency, reliability, permissions)
- A *DBA* often also designs the database, except for some complex projects

Transactions, Two Point of Views

- The user's:
  - any available software implementing an useful functionality/operation
- The system's:
  - unbreakable sequence of operations (see reliability)

Transactions (User's Point of View)

- Any software implementing frequent and well known operations, defined *a-priori*, with very few expected exceptions
- Examples:
  - paying money into one's account
  - issuing a birth certificate
  - a registration at the registry office
  - flight booking
- The transactions are implemented in a specific host language (either well known or "ad hoc")

DBMS: Pros

Pros

- data as a shared resource, databases modelling the environment
- standardizable and scaling up centralised data management
- provides integrated services
- reduces data redundancies and inconsistencies
- independence of data (supporting the development and management of software applications)

DBMS: Cons

Cons

- products can be costly as well as adopting such solutions
- functionalities are not detachable (the efficiency is reduced)