A (short) Introduction to Databases

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Topics we will cover

- Just a touch of history
- Why do we need databases
- What are they, anyway?
- How do they work (in a very basic form)
- Exercising database design

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(but feel free to ask about them if you feel so inclined, by any means :-))

- Advanced topics, such as:
    - search algorithms
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    - complex multi-table queries
    - sophisticated database functions
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Figure: A Leibnitz computing machine

- Back in the old days (I mean the eighteenth century). . .
- . . . computers were conceived and built for calculus and computation
- Mathematicians found out that reality was quite more complicate than the abstract models they had conceived. . .
- . . . so they invented "computing technologies", that is **computers**

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What are computers for? (2)

Figure: An IBM 7094 (1962)

- The last time computers were used *solely* for computing purposes was during World War II
- At the end of WW II, computing technology was mature enough to enter the industrial world. . .
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What are computers for? (3)

- Today, the most useful function of computers is. . .
- . . . their ability to **store and organize data**
- and this is where **databases** kick in.
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So why do we need databases? (1)

```
int i = 42;
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- As you all know, computers structure (and store) information in RAM memory
- Data maps into memory straight memory
- Memory is characterized by a content and an address (pointer)
- An address can also be considered some form of content

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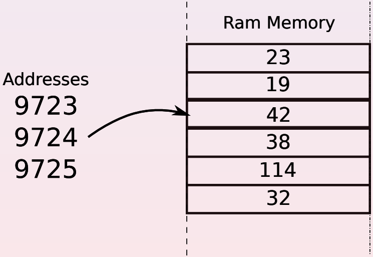

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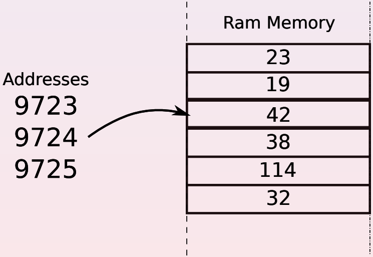

Ram Memory

23
19
42
38
114
32

Addresses
9723
9724
9725

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So why do we need databases? (2)

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struct birthday {
  int day;
  int month;
  int year;
};
```

- Furthermore, data in memory can be structured
- That is, it can be organized so that complex structures are kept physically together in RAM memory
- In the past few decades, these structures have become *object*, in object–oriented programming lingo

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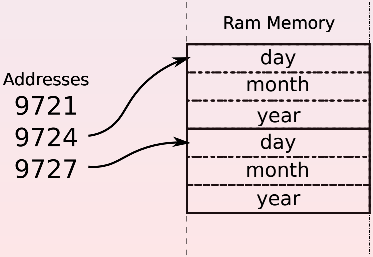

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- When the computer shuts off, the data is gone
- So: data needs to be *persisted*
- Which translates into: databases

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How many different kinds of databases are there?

- You can make databases (that is: save your data) with just about anything
  - log files
  - line oriented delimited text
    (f. ex. Nicola;Bernardini;Rome;14/08/1956;+4512345678)
  - spreadsheets
  - disk file systems
  - proper relational database
- only the last two do not save only *data* but also *relations*

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- If you start collecting data you soon realize that
  - a) either you repeat parts of the data endlessly
  - b) or you have to save *data relations* along with the *data* itself
- and here we get to the **golden rule of databases**, namely. . .

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The Golden Rule of Databases

DO NOT REPLICATE DATA.

Rationale for the golden rule

- You don't want to replicate data because you might need to change it in the future: if your data is replicated all over, you need to change it all over (very error-prone)
- while if you keep relationships instead, a single change will be sufficient for each piece of datum you have

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What are relations for? (2)

- This is what relations are for. For example:
  - If you have one *or more* telephone numbers for each person in your agenda (which is likely, or make it e-mail addresses, or whatever)
  - You need to be able to express something like “a person can *have many phone numbers*” or “this number *belongs to* this person”
  - Both sentences basically establish a *one–way relation* between persons and phone numbers

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struct person {
  char first_name[256];
  char last_name[256];
};

struct number {
  struct person *owner; /* <- */
  int number;
};

struct person persons[1000];
struct number numbers[10000];
```

- When your data is stored in RAM. . .
- . . . you represent relationships by *memory pointers* (also known as *references*) (check the arrow)
- but what happens when you want to *persist* the relationship? (== save it to disk)
- this (and some more) is what relational databases are for

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Before we go on, a question for you.

How would you create a persistent telephone book. . .
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- Current relational database can do much more than that
- Within databases, you
  - use a progressive number [illegible]
  - this number is guaranteed (by the database engine) to be unique
  - it is called the primary key
- Primary keys act like persistent pointers

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- These relationships are. . .

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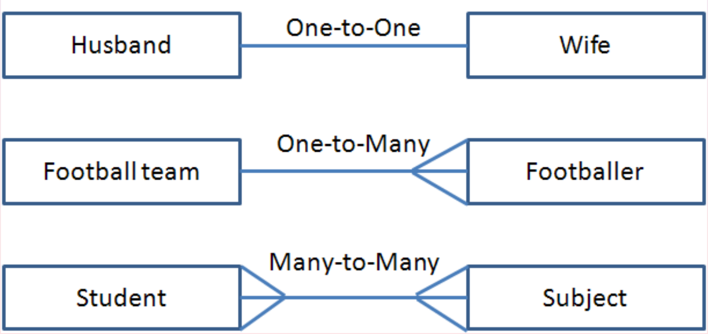

One–to–one relationships

- you establish one–to–one relationships by:
  - creating a first table with an auto–generated primary key
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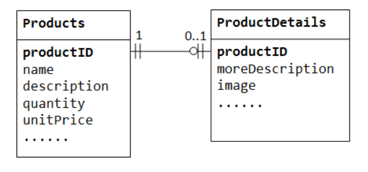

Products

productID
name
description
quantity
unitPrice
......

ProductDetails

productID
moreDescription
image
......

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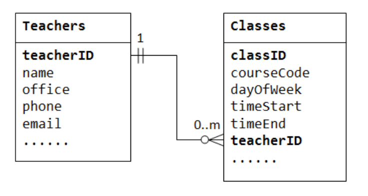

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Many–to–many relationships

- you establish many–to–many relationships by:
    - creating two separate tables with an auto–generated primary keys
    - creating a *third* table with *two* foreign keys each pointing to one instance of one of the first two tables

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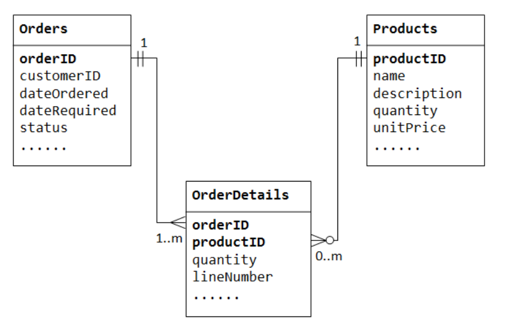
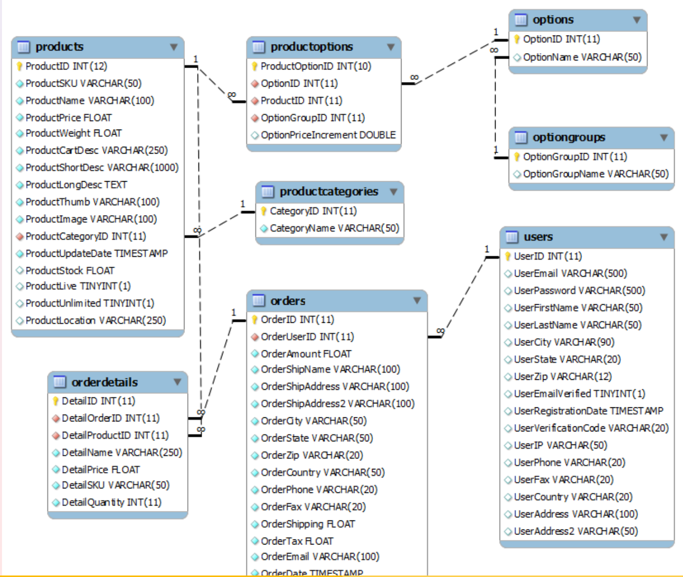


A real–world example



products
- ProductID INT(12)
- ProductSKU VARCHAR(50)
- ProductName VARCHAR(100)
- ProductPrice FLOAT
- ProductWeight FLOAT
- ProductCartDesc VARCHAR(250)
- ProductShortDesc VARCHAR(1000)
- ProductLongDesc TEXT
- ProductThumb VARCHAR(100)
- ProductImage VARCHAR(100)
- ProductCategoryID INT(11)
- ProductUpdateDate TIMESTAMP
- ProductStock FLOAT
- ProductLive TINYINT(1)
- ProductUnlimited TINYINT(1)
- ProductLocation VARCHAR(250)

productoptions
- ProductOptionID INT(10)
- OptionID INT(11)
- ProductID INT(11)
- OptionGroupID INT(11)
- OptionPriceIncrement DOUBLE

options
- OptionID INT(11)
- OptionName VARCHAR(50)

optiongroups
- OptionGroupID INT(11)
- OptionGroupName VARCHAR(50)

productcategories
- CategoryID INT(11)
- CategoryName VARCHAR(50)

users
- UserID INT(11)
- UserEmail VARCHAR(500)
- UserPassword VARCHAR(500)
- UserFirstName VARCHAR(50)
- UserLastName VARCHAR(50)
- UserCity VARCHAR(90)
- UserState VARCHAR(20)
- UserZip VARCHAR(12)
- UserEmailVerified TINYINT(1)
- UserRegistrationDate TIMESTAMP
- UserVerificationCode VARCHAR(20)
- UserIP VARCHAR(50)
- UserPhone VARCHAR(20)
- UserFax VARCHAR(20)
- UserCountry VARCHAR(20)
- UserAddress VARCHAR(100)
- UserAddress2 VARCHAR(50)

orders
- OrderID INT(11)
- OrderUserID INT(11)
- OrderAmount FLOAT
- OrderShipName VARCHAR(100)
- OrderShipAddress VARCHAR(100)
- OrderShipAddress2 VARCHAR(100)
- OrderCity VARCHAR(50)
- OrderState VARCHAR(50)
- OrderZip VARCHAR(20)
- OrderCountry VARCHAR(50)
- OrderPhone VARCHAR(20)
- OrderFax VARCHAR(20)
- OrderShipping FLOAT
- OrderTax FLOAT
- OrderEmail VARCHAR(100)
- OrderDate TIMESTAMP

orderdetails
- DetailID INT(11)
- DetailOrderID INT(11)
- DetailProductID INT(11)
- DetailName VARCHAR(250)
- DetailPrice FLOAT
- DetailSKU VARCHAR(50)
- DetailQuantity INT(11)

A structured query language (SQL) (1)

- Of course, structuring data is not enough to be able to use it efficiently
- You also need to have a way to create, browse, view, update, delete data
- Such a language exists: it is called *SQL* (spelled: *sequel* – which stands precisely for *Structured Query Language*)
- With minor changes, SQL can be used over a multitude of different databases (`sqlite`, `MySql`, `PostgreSQL`, `Oracle`, `Informix`, etc.)

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A structured query language (SQL) (2)

- SQL is a text–based language: you type some instruction on a database console and the database will reply with an answer
- Of course it can also be scripted and put into a file
- SQL has several commonly used statements:
- “SELECT”, [illegible]
- “SELECT” is the most commonly used, as it is the statement that allows you to make queries (it does not change the database)

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The “SELECT” statement (1)

Here is what the “SELECT” statement looks like:

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select "column1"
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The “SELECT” statement (2)

- Some “SELECT” examples:
  - `select first, last, city from employees where first like 'Er%';` find all first names that begin with 'Er' and display first name, last name and city of employee
  - `select * from employees where first = 'Eric';` find all first names that match the name 'Eric' exactly and display
  - `select last, city, age from employees where age > 30;` find all employees which are older than 30 years of age and display last name, city and age
  - `select last, city, age from employees where (age > 30) and (last like '%s');` find all employees which are older than 30 years of age and have a last name that ends in 's' and display last name, city and age
  - . . . let's do some examples live. . .

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- Some “SELECT” examples:
    - `select first, last, city from employees where first like 'Er%';` find all first names that begin with 'Er' and display first name, last name and city of operation
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Live examples

- Please download the employees.sqlite from Moodle
- If you have a Mac or a Linux laptop, you may open a terminal and type `sqlite3 employees.sqlite` in the folder where you downloaded the db
- if you have Windows, you may find a pre–compiled binary at `https://www.sqlite.org/download.html`

Walk-through exercise

- Let’s imagine reverse–engineering. . . FaceBook at least partially ;-)

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1. Pick your own data set and/or application
2. Design it in terms of a relational database:
    1. Establish tables
    2. Establish relationships among tables, making sure that no data is replicated
3. Discuss your design

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2. How they are conceived
3. What are data relationships
4. An introduction to the SQL language
5. How to design proper database structures (with some exercising)

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1. What are databases and why do they exist at all
2. How they are conceived
3. What are data relationships
4. An introduction to the SQL language
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THANK YOU!